

Integrated Chemical and Biological Defense Research, Development and Acquisition Plan

CHEMICAL & BIOLOGICAL POINT DETECTION DECONTAMINATION

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Integrated Chemical and Biological Defense Research, Development and Acquisition Plan: Chem-Bio Point Detection and Decontamination Technology Areas

Introduction

This report is the second annual edition of a series of interagency coordination documents that serve a dual purpose. First, they fulfill Counterproliferation Program Review Committee (CPRC) and Congressional coordination and reporting requirements¹ for the Department of Defense (DoD) and the Department of Energy (DOE) in the area of chemical and biological defense (CBD) research, development and acquisition (RDA). The first CBD RDA report published in April 2000² explained the rationale for and genesis of interagency coordination via the CPRC-chartered CBD Focus Group and the roles and responsibilities of DoD and DOE and other agencies.

The *Integrated Chemical and Biological Defense Program Research, Development and Acquisition Plan for the Departments of Defense and Energy: Bio Point Detection*, published in March 2001, presented the first technology area-focused roadmap. The narrower and more detailed scope of the roadmap reports serves the second and equally important purpose of the effort. The technology area roadmaps are "living" documents intended to facilitate coordination and cooperation between DOE and DoD at both the high level of national policy and planning and at the working level in the technology focus areas. They depict participating organization R&D programs and plans for testing and transitioning technologies into the acquisition process. Program data comes from existing planning documents in many cases; however, it should be noted that appearance within the roadmap does not imply funding commitments. Rather, the integration of these efforts into a single planning document represents a significant step toward a more formal, unified, long-term investment strategy.

The intent of the roadmaps is to allow agency leaders to have visibility across current and planned RDA efforts to avoid duplication of effort and to identify possible synergies and relevant research performed by their partner agencies. In addition, a key objective of the CBD RDA Focus Group³ is to provide useful information to Principal Investigators (PIs) and Program Managers (PMs) as well as to inform and enhance interaction among R&D scientists. The Bio Point Detection effort resulted in a general annual process for developing and then updating the technology areas. An annual report to the CPRC will include the updated technology area roadmaps for all areas covered; eventually a single Integrated Plan will cover all areas listed in Figure 1.

The pilot bio point detection roadmap was well received by the CPRC and the Deputy Assistant to the Secretary of Defense for Chemical and Biological Defense. As a result, the Focus Group was directed to:

- Expand the technology areas covered beyond bio point detection
- Expand DoD/DOE roadmapping process to include a broader set of organizations

¹ See Appendix D for the congressional language establishing these requirements.

² Integrated Chemical and Biological Defense Research, Development and Acquisition Plan for the Departments of Defense and Energy, Counterproliferation Review Committee, April 2000.

³ The Focus Group includes decision-makers and area experts from CBD, DARPA and CBNP.

This second report is responsive to the above guidance. It includes both an expanded bio point detection roadmap, which now covers chemical point detection as well, and the decontamination roadmap (see Figure 1 for progress to date). In addition, the Technical Support Working Group (TSWG), the Department of Justice (DOJ) and the Defense Threat Reduction Agency (DTRA) provided input to this year's report. Intelligence community representatives have participated in Focus Group meetings. Coordination has begun with the Nonproliferation and Arms Control Technology Working Group (NPAC TWG).

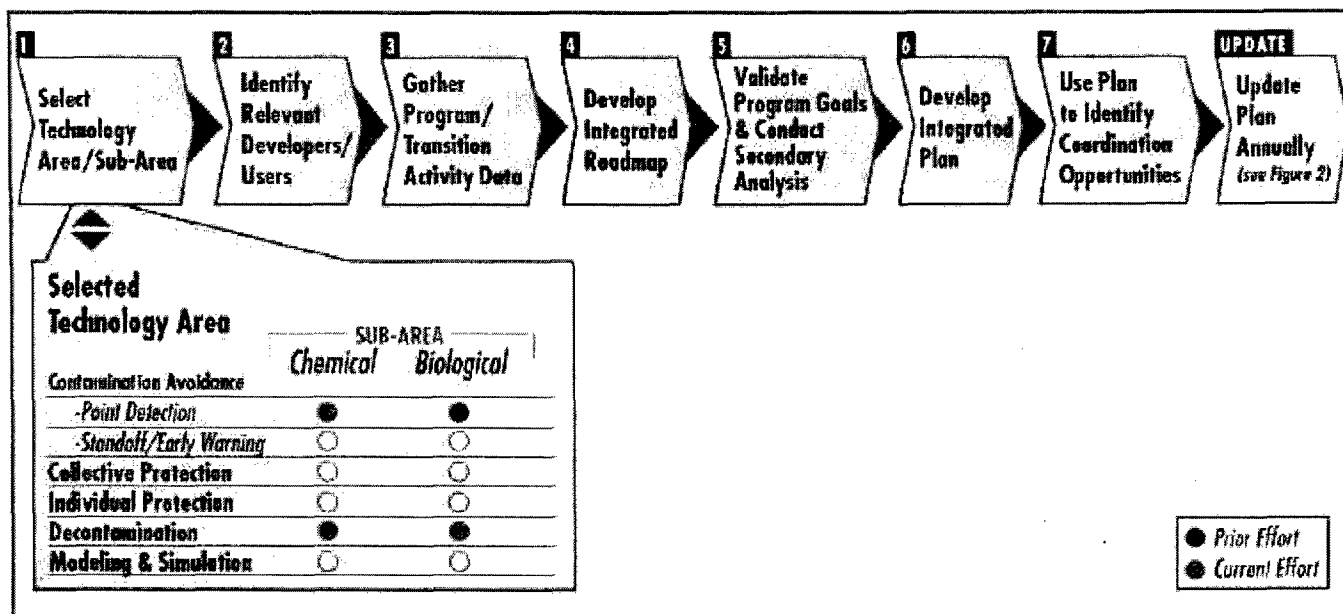
Methodology

The integration template developed during last year's pilot effort has two essential elements:

- A format for an integrated technology area Roadmap
- A repeatable process by which the Roadmap is first developed and then annually reviewed and updated

As additional technology areas are addressed, the template and the development and updating process will be repeatedly tested and improved, culminating in a comprehensive Integrated Plan.

Figure 1. Technology Roadmap Development Process & Progress To Date



Selection of a technology area and identification of stakeholders (developers and users) are the first steps in the roadmap development process. The next step is to determine what specific data is relevant to increased interagency RDA transparency. This data includes:

- Timelines for anticipated acquisitions (e.g., Engineering and Manufacturing Development programs (EMD) such as the Joint Biological Point Detection System

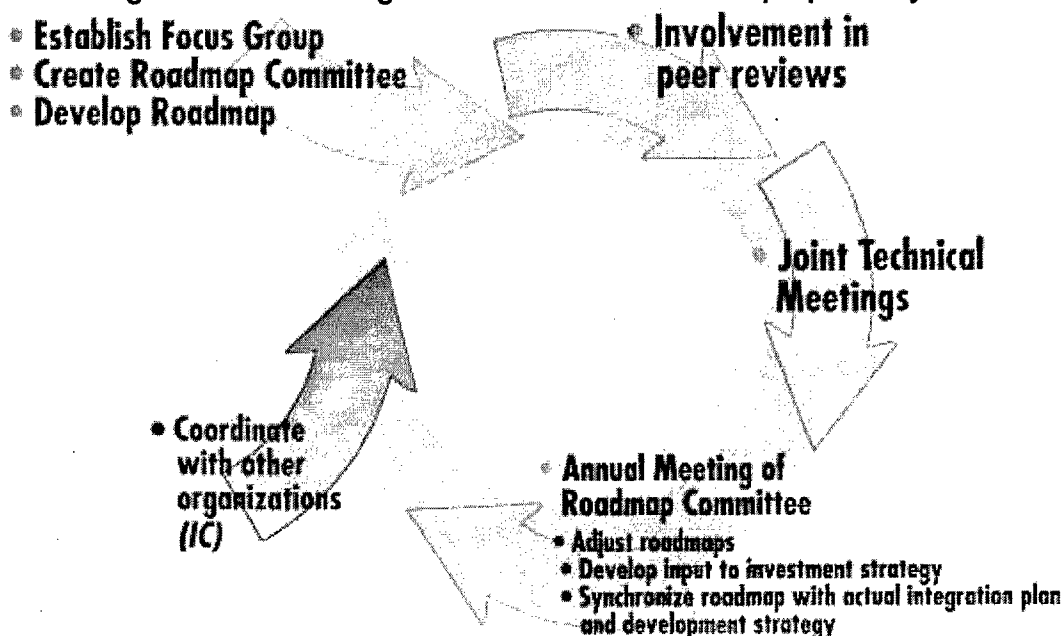
(JBPDS) and the Joint Service Multispectral Chemical and Biological Detector (JSMCBD⁴))

- Top-level guidance (Joint Future Operational Capabilities (JFOCs), Areas for Capability Enhancements (ACEs))
- Testing and demonstration activities and key events (*e.g.*, Advanced Technology Demonstrations/Advanced Concept Technology Demonstrations (ATDs/ACTDs), Joint Field Trails (JFTs), Domestic Demonstration and Application Programs (DDAPs))
- Technology area R&D programs: timelines and key milestones, including participation in testing and demonstration activities

By showing R&D program timelines, transition timelines and testing activities in a single graphic, the roadmap provides a panoramic look ahead for a given technology area. The above data must be gathered from each agency's existing planning documents, program managers (PMs) and principal investigators (PIs) in order to complete the roadmap.

Figure 2 depicts the annual roadmap development and update process; note that there are no set timelines, with the exception of the annual meeting of the Roadmap Committee. This is because, although the process is applicable to all technology area roadmaps, it will involve interaction with some different sets of developers and users for each, so the timing of annual cycles may differ slightly. Ideally, all roadmap updates should be completed in time to influence development of investment strategies.

Figure 2. Annual Integration Process and Roadmap Update Cycle



The process steps depicted in Figure 2 and briefly described below apply to all technology area roadmaps, but examples and details are based on the bio point detection roadmapping process. It should be noted that the process is still under development and will continue to be tested and modified as technology area coverage and interagency participation is broadened.

⁴ See Appendix A for a description of these programs.

The process includes the following steps.

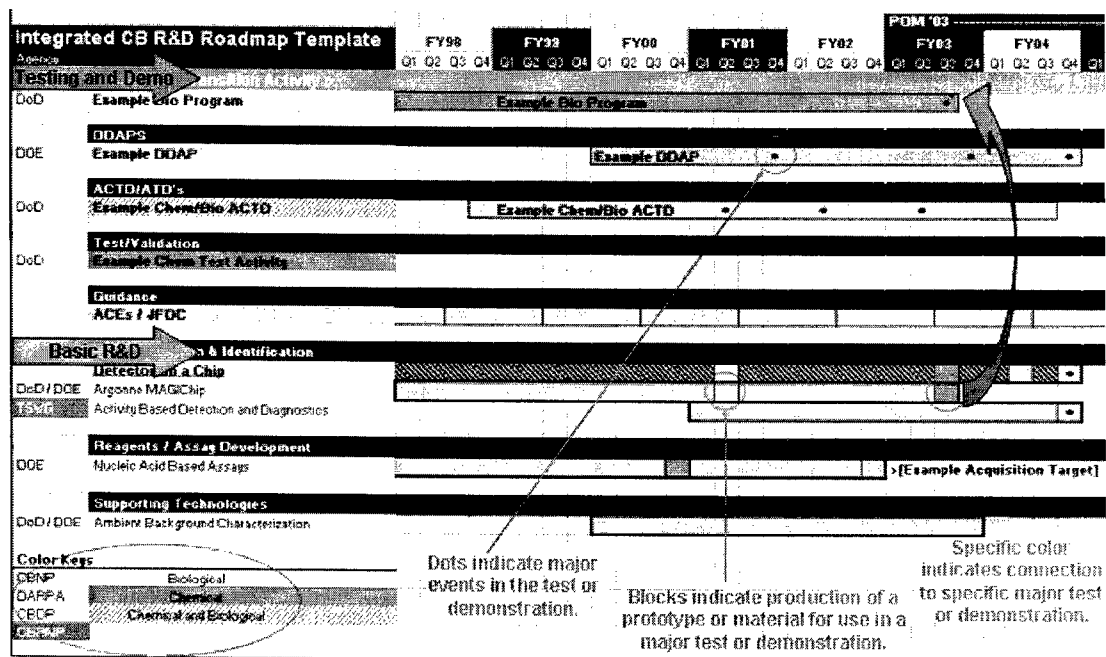
- Establishment of the Roadmap Committees, which are technology area sub-committees of the Focus Group; this occurs only once, during overall process development. The Focus Group identifies Roadmap Committee members for each technology area and has done so for bio point detection. Roadmap committees include, at a minimum, the DoD Joint Service Business Area Manager (BAM), the DOE Chemical Biological National Security Program (CBNP) PM, and DARPA and TSWG representation.
- Establishment of the initial technology area roadmaps, once for each technology area, by the designated Roadmap Committees. These initial roadmaps are then reviewed and adjusted annually.
- Cross-organizational involvement in peer reviews, to facilitate identification of any potential duplication of effort or opportunities to cooperate and leverage synergies across programs and demonstrations. This is an ongoing activity, but should acquire new emphasis as the roadmapping process proceeds. This cross-organizational involvement is required to deconflict planning and develop shared expectations across the technology area community.
- Regular joint detection meetings at the PI level to ensure continuous progress on deconfliction and integration. These meetings must occur at least annually for each technology area Roadmap Committee to review and update the roadmaps in time for the annual spring meeting of the Focus Group. Each Committee has the latitude to select an opportune technical conference around which to schedule an update meeting.
- Special focus technology meetings that bring in key members of the user-developer community, when deemed appropriate by the detection PIs, the technology area Roadmap Committee, or the Focus Group. Such meetings may occur if a developing technology is under consideration for inclusion in a transition testing or demonstration activity, for example.
- Coordination with other organizations, including the intelligence community (IC) overall and specific organizations, such as Measurement and Signature Intelligence (MASINT), and other CPRC member organizations.
- The annual roadmap development, review and update process will culminate in a spring meeting of the Focus Group to review progress on all technology area-specific CBD RDA plans; adjust the roadmaps as needed; and develop investment strategies. It is critical that this meeting take place in the spring, in time to affect the POM update cycle.

The Roadmap Template

The first product defined in the above methodology is a template for the Technology Area Roadmaps. The intent of the Roadmap template is to provide a tool for depicting DoD and DOE R&D programs and the means and timing of their integration into Testing, Demonstration and Acquisition activities in order to facilitate cross-organizational awareness and cooperation. Such cooperation will assist in eliminating unnecessary duplication of DoD/DOE R&D efforts as well as provide a means for productive interagency leveraging.

Figure 3 shows the general Roadmap template, which is separated into two main sections. The top section consists of Acquisition/Transition Activities, whereas the lower section comprises R&D Programs in a given technology sub-area. Funding and executing entities responsible for these activities and programs are listed in the column on the far left. The Acquisition and Transition Activities listed are exercises/events that provide technology insertion points for Sensor/System program deliverables. Acquisition/Transition Activities include CBDP EMD programs, DOE DDAPs, DoD ATD/ACTDs, DoD/DOE Test/Validation Programs and Guidance documents.

Figure 3. The General Roadmap Template



Each technology area Roadmap is color coded for clarity and can be viewed at the summary level (aggregated technology sub-area groupings) or at the individual program level:

- The far left column lists the agency (DOE, DoD, TSWG) under which the research effort listed in the next column to the right falls. The color coding in the far left column designates the division, program, or sub-group within each of these agencies that owns the research effort. In this example, CBNP (DOE) activity/program titles on the left are shaded in orange; DARPA (DoD) activities are light blue; and CBRNP (TSWG) activities are purple. CBNP (DoD) activity/program titles are not shaded.

- The timeline bars associated with each Acquisition/Transition Activity are also uniquely colored. Black and white dots are placed within these timeline bars to denote a major test or demonstration will take place in a specific activity. Black dots designate “hard” milestones, those which at which a firmly scheduled activity or event occurs. White dots represent “soft” milestones—timing goals rather than firm events.
- For each group of similar programs (*e.g.*, Detector on a Chip), a summary bar extends across the timeline in black/gray diagonal shading. The bar includes all milestone activities for the programs within the group, in this case Argonne MAGIChip and Activity Based Detection and Diagnostics. As the number of programs covered in the point detection roadmap grows, these bars will allow the presentation of a summary roadmap, by technology group, on a single page. Program-level roadmaps can be included behind the “big picture” summary.
- R&D program involvement in an Acquisition/Transition activity is shown on the program timeline bars. A block in color denoting the Acquisition/Transition activity is inserted to depict the specific test/demonstration and time period that an R&D deliverable will be tested or demonstrated. A black vertical border at the first year covered by the Roadmap denotes a new start; programs without the border line were ongoing prior to the time period covered by the Roadmap.
- At the end of a program timeline, the transition target is listed; in some cases, this will be commercial.

Technology Area Roadmaps and Analyses

This report includes both the newly integrated chem-bio point detection roadmap and the new decontamination roadmap. In addition to the graphic roadmaps, the report includes the following information, to be included in each annual report edition:

- Summaries of acquisition and transition activities are provided for both roadmaps. Transition/Acquisition and Project/Program details can be found in Appendix A for chem-bio point detection and in Appendix B for decontamination.
- Current programs and projects are grouped into key technology sub-areas in both roadmaps; the rationales for the classification and key characteristics of each grouping are discussed.
- The roadmap report Findings sections, which are separate for each technology area covered, discuss the impact of the cooperative planning undertaken as a result of the roadmapping initiative. Both successes and challenges are identified.
- Each annual edition of this report includes at least one redundancy analysis of a selected research approach within a technology area covered by the report. This is summarized in Figure 4, which will be updated annually. The purpose of this analysis is to ensure that is no unnecessary duplication of effort among the funded programs within the technology area. Last year's report included an analysis of mass spectrometry efforts. Results of a redundancy analysis of ongoing oxidative chemistry research programs are included in the decontamination roadmap Findings section. The full redundancy analysis can be found in Appendix C.

Figure 4. Progress on Technology Area Roadmaps and Redundancy Analyses

Report Technology Areas	Year	Redundancy Analysis
Biological point detection	2001	Mass spectrometry
Chemical and biological point detection and decontamination	2002	Peroxy-based oxidative decontamination approaches
Chemical and biological point detection, decontamination and modeling and simulation	2003	TBD

The Chem-Bio Point Detection Roadmap

The summary level updated and expanded Bio Point Detection Roadmap, now the Chem-Bio Point Detection Roadmap, is shown in Figure 5 on the following two pages. The Roadmap covers relevant Acquisition/Transition activities and R&D programs from FY00 through FY11.

Figure 5. The Chem-Bio Point Detection Roadmap

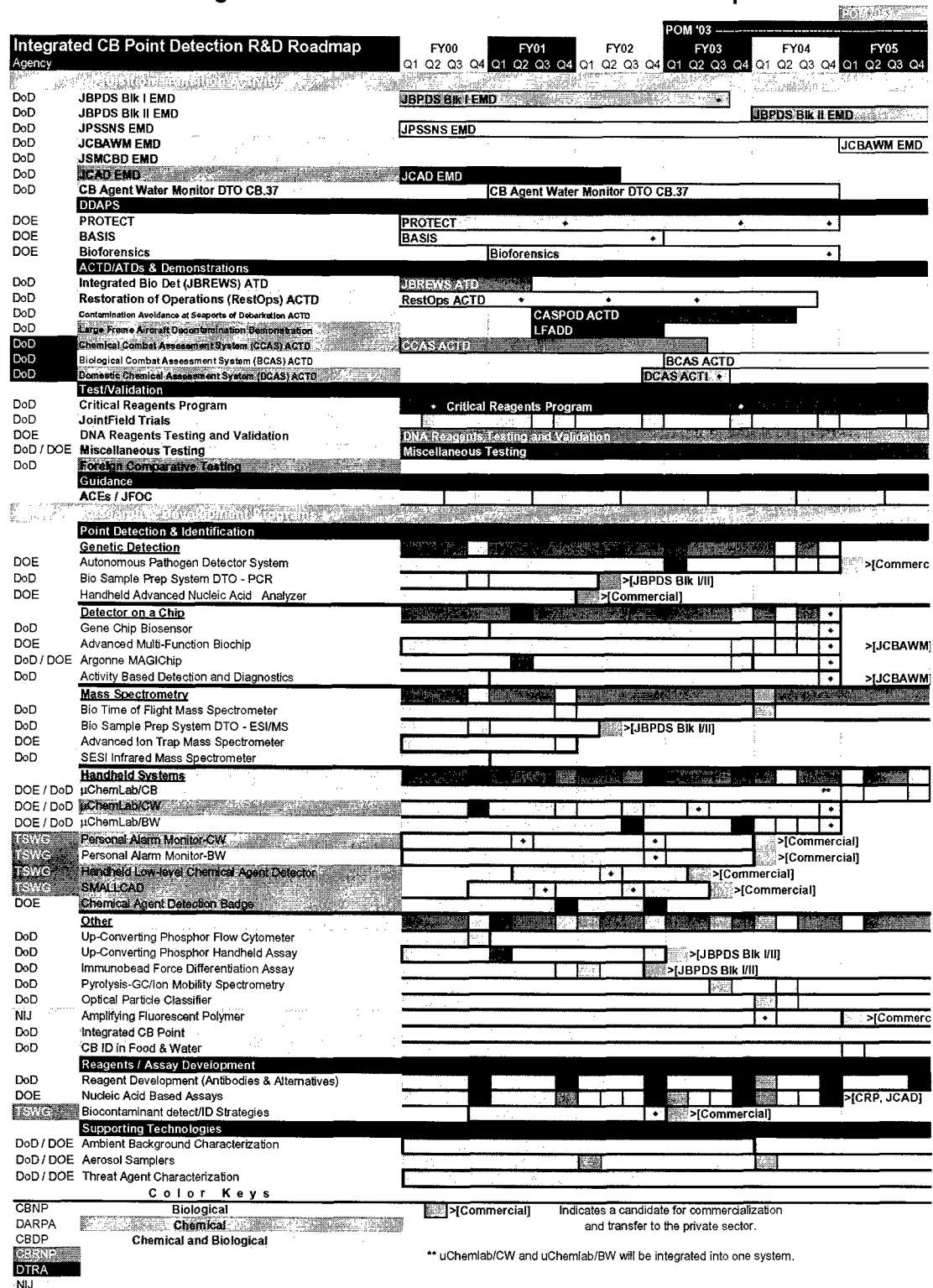
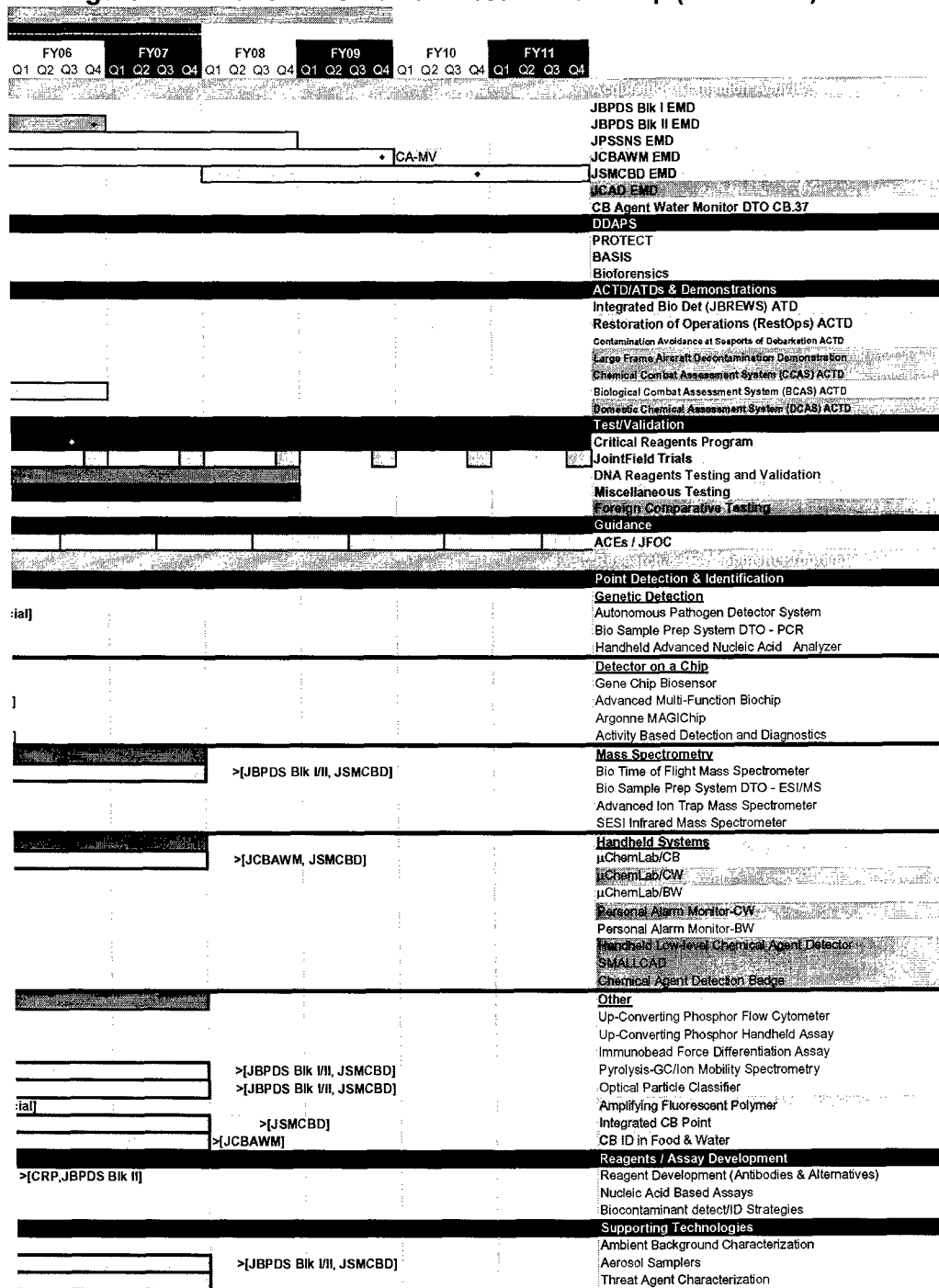


Figure 5. The Chem-Bio Point Detection Roadmap (Continued)



Acquisition/Transition Activities Involving Chemical and Biological Detection Technologies

The transition and acquisition activities to which DoD and DOE CB point detection R&D programs make significant contributions include six DoD programs in the EMD acquisition phase; three DOE Domestic Demonstration and Application Programs (DDAPs); five DoD Advanced Concept Technology Demonstrations (ACTDs); and several types of testing and validation programs. Two of the EMD programs (JPSSNS and JBPDS) support biological agent detection exclusively. One program (JCAD) supports chemical agent detection exclusively, and three (JCBAWM, JSMCBD, DTO CB.37) support both chemical and biological detection. The DDAPS and ACTDs are also grouped according to detection preference. BASIS and Bioforensics DDAPs are designed for biological detection only, whereas the PROTECT DDAP addresses both chemical and biological detection. The JBREWS and BCAS ACTDs focus on biological agent detection; CCAS and DCAS focus on chemical agent detection; and RestOps addresses both types of agents.

The DoD transition and acquisition activities, as well as the supporting R&D programs, contribute to requirements developed in two key pieces of guidance:

- The Joint Future Operational Capabilities (JFOCs) list developed by the Joint Services
- The prioritized CPRC Areas for Capability Enhancement (ACEs)

Specifically, activities and programs included in the CB Point Detection Roadmap support the development of warfighting capabilities for ACE 1: Detection, Identification, Characterization, Location, Prediction and Warning of CW and BW agents.

Chemical and Biological Detection: Current Programs and Projects

Sensor/System R&D programs include Chemical and Biological Point Detection and Identification, Reagents/Assay Development, and Supporting Technologies. Biological Point Detection and Identification Programs are further subdivided into major activity areas: Genetic Detection, Detector on a Chip, Mass Spectrometry and other programs that have not yet been categorized. At this time, Chemical Point Detection and Identification Programs have not been categorized and are currently grouped in the "Other" Technology group. A detailed description of these activities and programs can be found in Appendix A.

In developing the roadmap, the Focus Group identified several "like" biological R&D programs that have been grouped together. While three of these groups (Genetic, Chip, Mass Spec.) are based on common technology platforms, program approaches explore different ways of applying the underlying technology. Figure 6 provides a summary overview of the technology groupings and shared technology platforms. The table also includes supporting technologies that will contribute to the other more mature groups once they are better defined. Each program is identified as bio-focused (B), chem-focused (C) or as a program with both chemical and biological applications (CB).

Figure 6. Sensor/System R&D Technology Groupings

Technology Group	Programs	Shared Technology Platform
Detection and Identification		
Genetic Detection	<ul style="list-style-type: none"> • APDS B • BSPS-PCR B • HANAA B 	PCR for genetic detection of bacterial and viral agents
Detector on a Chip	<ul style="list-style-type: none"> • Gene Chip Biosensor B • Advanced Multi-function Biochip B • Argonne MAGIChip B • Activity Based Detection and Diagnostics B 	Microchip platform for detection
Mass Spectrometry	<ul style="list-style-type: none"> • Bio-ToF MS B • BSPS-ESI/MS B • Advance Ion Trap MS B • SESI IR MS B 	Mass spectroscopy methodologies for sample handling/analysis
Handheld Systems	<ul style="list-style-type: none"> • μChemLab/CB CB • Personal Alarm Monitor-CW C • Personal Alarm Monitor-BW B • Handheld Low-level Chemical Agent Detector C • SMALLCAD C • CADB C • HANAA B • UCPHHA B 	Systems optimized for handheld use
Other	<ul style="list-style-type: none"> • UCPFC B • Immunobead Force Differentiation Assay B • Pyrolysis-GC/Ion Mobility Spectrometry B • Optical Particle Classifier B • Amplifying Fluorescent Polymer CB • Integrated CB Point CB • CB ID in Food & Water CB 	N/A—each platform is unique
Reagent/Assay Development		
	<ul style="list-style-type: none"> • Reagent Development with Antibodies & Alternatives B • CBNP Nucleic Acid-Based Assays B • Biocontaminant detect/ID Strategies B 	Goal of programs is shared, but the nucleic acid-based program differs from the antibody programs
Supporting Technologies		
	<ul style="list-style-type: none"> • Ambient Background Characterization B • Aerosol Sampler Development B • Threat Agent Characterization B 	Immature technologies not yet fully defined; will eventually contribute to the bio point detection technologies listed above

Findings

Cooperative Planning

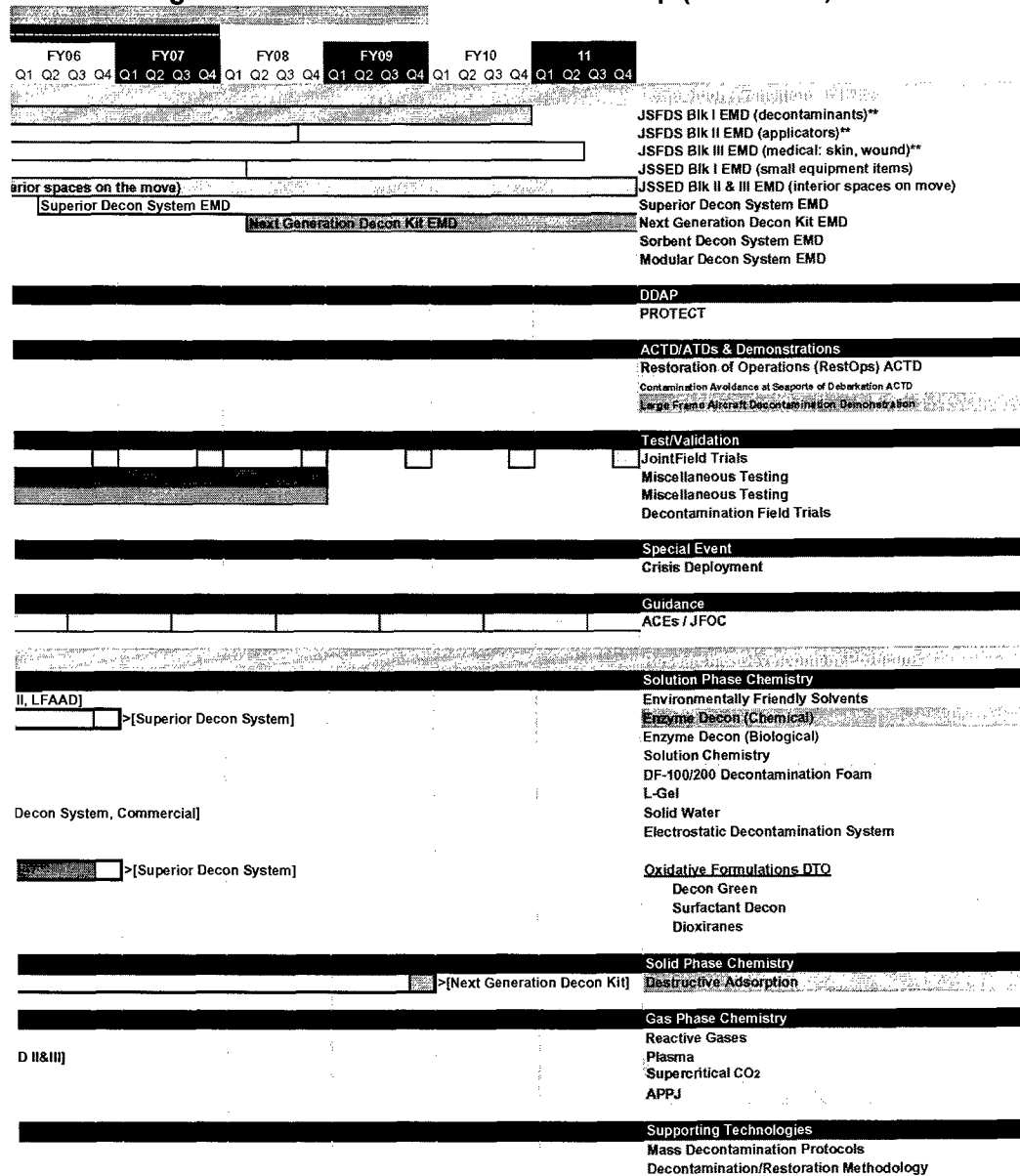
The integration effort has also had an early influence on sensor system participation in planned acquisition/transition testing. Clearly, the integrated chem-bio point detection roadmap seen above demonstrates a reasonably integrated effort. The current roadmap represents substantial progress in cooperative planning over the initial roadmap that was generated in the early stages of the integration effort. For example, comparison of the old and new versions shows a significant increase in the number of interagency integration opportunities that have been identified and will now be exploited for sensor system R&D items. This increase is mainly due to regular Focus Group meetings. Increased participation has included the Technology Support Working Group (TSWG), and efforts are underway to reach out to the Nonproliferation and Arms Control Technology Working Group (NPAC TWG) to integrate their Real-Time PCR Identification into the Roadmap. Additionally, executive agents for the JBPDS EMD have recently increased their participation in the roadmap effort, since it provides them a consolidated list of technology options for consideration in the event that fielding problems occur or requirements change.

The roadmap has also helped Focus Group members to identify an important planning gap: it clearly shows a significant reduction in planned transition and acquisition activity after FY04. This means that several nascent but mission-critical technologies may not make it into the hands of the user if suitable transition opportunities are not identified to bring them to the field. The purpose of the Integrated Plan is to ensure that planning for these technologies is based on a strategic vision with a horizon beyond current POM or budget cycles, though detailed funding requirements will not be articulated until a given activity is within the budgetary timeline. Regular Focus Group meetings must therefore continue, in accordance with the new annual process articulated above, in order to articulate proactively the R&D community's requirements for transitioning critical chemical and biological detection technologies to the field, thus buttressing efforts to assure adequate and timely funding.

The Decontamination Roadmap

The summary level Decontamination Roadmap is shown in Figure 7 on the following two pages. The Roadmap covers relevant Acquisition/Transition activities and R&D programs from FY00 through FY11.

Figure 7. The Decontamination Roadmap (Continued)



Acquisition/Transition Activities Involving Decontamination Technologies

The transition and acquisition activities to which DoD and DOE CB Decontamination R&D programs make significant contributions include six DoD programs depicted during their EMD acquisition phase, one DDAP, one ACTD and several types of testing and validation programs. The EMD programs include JSFDS, JSSED, Superior Decon System, Next Generation Decon Kit, Sorbent Decon System and Modular Decon System. All EMD programs are designed to address both chemical and biological decontamination, as are the PROTECT DDAP and RestOps ACTD programs.

The DoD activities, as well as the supporting R&D programs, contribute to requirements developed in two key pieces of guidance:

- The Joint Future Operational Capabilities (JFOCs) list developed by the Joint Services
- The prioritized CPRC Areas for Capability Enhancement (ACEs)

Specifically, activities and programs in the CB Decontamination Roadmap support the development of warfighting capabilities for ACE 2: Enable sustained operations in an NBC environment through decontamination, and individual and collective protection.

Decontamination: Current Programs and Projects

Decontamination R&D programs are divided into four major technology areas including Solution Phase Chemistry, Solid Phase Chemistry, Gas Phase Chemistry and Supporting Technologies. Figure 8 provides a summary overview of the technology groupings and shared technology characteristics. Shared technology characteristics identified by the Roadmap Committee fall into four major areas including Oxidative Chemistry, Enzyme-based, Sensitive Equipment and Methodology Verification. Although each area identifies similarities in technologies, the approach used by each research effort is unique. A detailed description of these activities and programs can be found in Appendix B.

Figure 8. Decontamination Technology Groupings

Technology Group	Programs	Shared Technology Characteristics
Solution Phase Chemistry		
	• Environmentally Friendly Solvents CB	Oxidative Chemistry
	• Decon Green CB	
	• Surfactant Based Decon Solution CB	
	• Dioxiranes CB	
	• DF-100 (Sandia Foam) CB	
	• L-gel CB	
	• DARPA Solution Chemistry B	to be provided
	• Enzyme Decon (Chemical) CBDP C	Enzyme-based
• Enzyme Decon (Biological) DARPA B		
• Electrostatic Decontamination System CB	Photoactivated system	
Solid Phase Chemistry		
	• Destructive Adsorption C	Reactive nanoparticles
Gas Phase Chemistry		
	• Plasma CB	Sensitive Equipment
	• APPJ CB	
	• Supercritical CO ₂ CB	
	• Reactive Gases CB	
Supporting Technologies		
	• Decon/Restoration Methodology CB	Methodology Verification
	• Mass Decon Protocols CB	

Findings

Redundancy Analysis

The Decontamination Roadmap redundancy analysis⁵ focused on the area of oxidative chemistry decontamination research in DoD and DOE. Oxidative chemical approaches form the basis of the solution chemistry thrust effort of both departments. All of the various programs (listed in Figure 7, above) are based on incorporating peroxy-containing species as the active component in their decontamination solutions. This common thread allows the various investigators to maximize leveraging opportunities while minimizing redundancy among the projects. The various approaches under development yield different levels of efficiency, effectiveness and environmental friendliness.

For example, DF-100/200 and Decon Green both use hydrogen peroxide as the active component, but their base formulations are drastically different. The Decontamination Foam (DF)-100/200 products are aqueous-based solutions that can be concentrated and later mixed with water onsite to provide the decontaminant. This characteristic is particularly beneficial from a logistical and application standpoint, but some sacrifices are made because many chemical agents and thickeners are organic compounds and not very soluble in aqueous solutions. Decon Green on the other hand is an organic solution; chemical agents and thickeners are very soluble in this solution. The organic nature of Decon Green, however, makes concentration difficult, which can be problematic for both logistics and the application. In turn, decontamination requirements

⁵ See Appendix C for the full redundancy analysis.

vary based on the target material for decontamination—decontaminating computer equipment is a different problem than decontaminating a cement floor.

The redundancy analysis revealed that the programs above constitute a group of promising decontamination options, none of which relies upon the same approach to decontaminate similar materials that have been affected by the same agents. Some have been developed explicitly for military applications, while others are intended for domestic use. Many have potential in both areas.

Cooperative Planning

Oxidative chemistry-based decon was initially limited to chemical agents; however, over the past decade or so, promising efforts to develop approaches that work for biological agents have been underway. Development of oxidative chemistry-based decontamination solutions clearly exemplifies the close interaction between DoD and DOE decontamination development programs.

A two-year DF-200 CB3 Technology Transfer effort exemplifies the close interaction between DoD and DOE on refinement of DF-100 and its upgrade to DF-200. DOE initially leveraged basic research done by DoD and developed an effective product for a domestic response scenario. DoD recognized the potential of DF-200 and provided recommendations on ways to improve the product to meet military requirements and ultimately incorporated advanced development and testing efforts into its 6.3 level program. These efforts will not only provide an improved product for DOE to use in domestic response scenarios, they will also provide DoD with an effective aqueous-based oxidative decontamination solution.

There has been a great deal of leveraging between DoD and DOE on the oxidative chemistry program. The principal investigators (PIs) have jointly attended multiple meetings, workshops and symposia on these projects. Of particular note are the 2000 New Concepts in Decontamination Workshop co-sponsored by the Joint Science and Technology Panel for Chemical and Biological Defense (JSTPCBD) and the Army Research Office and the annual DOE CBNP Summer Meetings. To ensure leveraging continues in this area, the JSTPCBD Business Area Manager is serving as a liaison between DOE researchers and the PI's working on the DoD funded efforts. This will minimize the potential for organizational conflicts of interest and ensure that, when appropriate, DOE technologies have a link to DoD decontamination activities.

One striking example arose from real-world need for and subsequent use of a DOE-developed decontamination product. In the aftermath of the October 2001 anthrax incidents, several facilities required decontamination. DF-100, developed at Sandia and currently in commercial production, was used to help remediate office buildings on both Capitol Hill and in New York City which were contaminated as a result of the anthrax incidents of late 2001.⁶ Over the next few weeks, DF-100 remediated a large mailroom facility in the Ford House Office Building, a large mailroom in the Dirksen Senate Office Building, and selected hallways, stairways and a freight building in the Hart Senate Office Building. There was minimal collateral damage in the first application (the Ford mailroom) due to overapplication of the foam, a result of operator inexperience. This was a learning experience that highlights the need for close coordination between product R&D organizations and intended end users. No collateral damage was noted in the second and third applications (in the Dirksen and Hart Buildings). DF-100 was

⁶ See Appendix C for a more detailed discussion of the use of DF-100 in response to the 2001 anthrax incidents.

also used to remediate the ABC News Building and New York Post Building in New York City. No negative health effects have been noted in either building.

Conclusion

Both the CB Point Detection and the CB Decontamination Focus Group members believe that their efforts to foster CBD RDA integration between DoD and DOE have yielded progress over the past year.

- First, the groups successfully applied the Roadmap template and process developed last year, yielding a Point Detection Roadmap that includes both chemical and biological detection efforts as well as a Decontamination Roadmap, also covering both chemical and biological decontamination R&D.
- Second, last year's progress in interagency coordination of mass spectrometry efforts and in interagency knowledge leveraging in detection on a chip is continuing, expanded this year by the dialogue that has taken place to review oxidative decontamination approaches under development in DOE and DoD. The PIs that have taken part in these interactions intend to continue to coordinate and identify leveraging opportunities.
- Third, the groups have expanded their membership to include TSWG, NIJ, DTRA and some representatives of the IC, with overtures to the NPAC TWG ongoing.
- Finally, last year, the cooperative planning process identified the need to address the significant gap in FY05 and beyond of opportunities to transition biodetection technologies now under development to users who need those technologies to meet their WMD mission driven security needs.

In the aftermath of September 11, 2001 and the subsequent mailings of anthrax-tainted letters, these efforts have taken on a renewed sense of importance and urgency to support emerging requirements for Homeland Defense in both detection and decontamination.

APPENDIX A

Acquisition/Transition Activities Involving CB detection Technologies

The transition and acquisition activities to which CB point detection research and development programs and DoD and DOE make significant contributions are introduced below. They include five EMDs (JPBDS, JPSSNS, JCBAWM, JMCBD and JCAD), one DTO (CB.37), three DOE DDAPs (PROTECT, BASIS and Bioforensics), seven ACTD/ATDs (JBREWS, RestOps, CASPOD, LFADD, CCAS, BCAS and DCAS), and several types of testing and validation programs. The DoD activities, as well as the supporting R&D programs, contribute to requirements developed in two key pieces of guidance: the Joint Field Operational Capabilities (JFOCs) list and the Areas for Capability Enhancement (ACEs) identified as necessary to the achievement of the JFOCs.

Engineering and Manufacturing Development (EMD) Programs

JBPDS EMD: DoD CBDP

The Joint Biological Point Detection System (JBPDS) program will provide a common integrated biological point detection suite for use by all services. It will be used to protect air bases, ports, ships and forces. It will automatically detect and identify 10 biological warfare (BW) agents. The focus of **JBPDS Blk I** is automation and increasing the number of BW agents identified. JBPDS Blk I is currently in LRIP with IOT&E scheduled for FY02. A major challenge being addressed for Operational Testing is whole-system, live, pathogenic agent testing versus component-level testing. The needs for testing in various locations, real-time data acquisition, and reduced test costs require a standoff-type referee system. To improve reliability, a hardened calibration and confidence device is planned. **JBPDS Block II** efforts are centered on decreasing system size, weight and power and increasing system sensitivity. A major component for improvement will be the advanced BAWs to increase sensitivity and to reduce operation cost. The program timeline is FY98 through FY06. The roadmap shows possible candidate R&D systems for block II transition. These include: BSPS-PCR, BSPS-ESI/MS, Bio-ToF MS, Immunobead Force Differentiation Assay, and Optical Particle Classifier.

JPSSNS EMD: DoD CBDP

The XM99 Joint Portal Shield Sensor Network System is a fielded, point detection system currently in production and utilized by the Commanders in Chief (CINCs) of both Pacific Command (PACOM) and Central Command (CENTCOM) to provide biological detection capabilities for fixed sites (ports of embarkation/debarkation) against small-scale releases. The JPSSNS was initiated as an Advanced Concept Technology Demonstration (ACTD) to evaluate the military utility of a biological detection network capability, to develop operational procedures for that capability, and to provide a residual capability to detect, warn, de-warn and presumptively identify a BW attack on a high priority fixed site. The Joint Portal Shield system is a network of sensors linked to a central Command Post (CP) computer that monitors the operational status of the sensors, controls the networked sensors, evaluates network data to determine if a BW attack has occurred, and alerts the operator to a BW event. The program timeline shows activity through FY08.

JCBAWM EMD: DoD CBDP

The Joint Chemical Biological Agent Water Monitor project will have the capability to detect, identify and quantify CB agents in source, treated and distributed potable water supplies. Technologies for JCBAWM are being investigated under the CB Agent Water Monitor DTO. A

market survey identifying and ranking some 150 technologies was conducted, with five technologies being selected for focused investigation. These technologies are Attenuated Total Reflectance-FTIR, Molecular Imprinted Polymer Sensor, Dendrimer-based Antibody Assays, Pyrolysis-GC-ion mobility spectrometry, and surface enhanced Raman spectroscopy. Data are being developed to support downselect of technologies to be incorporated in breadboard build in FY03 with demonstration in FY04. Target transition is to Joint Chemical Biological Agent Water Monitor EMD in FY05. The roadmap shows possible candidate R&D systems for transition into JCBAWM to include Advanced Multi-Functional Biochip, Activity Based Detection/Diagnostics and μ ChemLab/CB. The program timeline is FY05-09.

JSMCBD EMD: DoD CBDP

The Joint Service Multispectral Chemical Biological Detector program goal is to generate a detection device that can be used alone or in networks and can identify both chemical and biological agents. This system begins EMD in FY08. The roadmap shows possible candidate R&D systems for transition into JSMCBD to include Bio Time of Flight Mass Spectrometer, the Advanced Multifunction Biochip, μ ChemLab, Pyrolysis-GC/Ion Mobility Spectrometry, Optical Particle Classifier, and Aerosol Samplers. The program timeline is FY08-11.

JCAD (DoD): DoD CBDP

The focus of the Joint Chemical Agent Detector (JCAD) RDTE effort is to develop a point chemical vapor detection system that will satisfy a range of military requirements and platforms. Service requirements include: Individual Soldier Detection (ISD), Special Operation Force Chemical Agent Detector (SOFCAS), Individual Vapor Detector (IVD), Aircraft Interior Detector (AIDET), Shipboard Chemical Agent Monitor Portable (SCAMP), CW Interior Compartment System (CWICS) and Improved Chemical Detection System (ICDS). The system is currently under development and is scheduled for procurement and fielding. The current program timeline shows activity into FY02.

CB Agent Water Monitor DTO: DoD CBDP

The Agent Water Monitor project is investigating technologies to develop a capability to detect, identify and quantify CB agents in source, treated and distributed potable water supplies. A market survey identifying and ranking some 150 technologies was conducted, with five technologies being selected for focused investigation. These technologies are Attenuated Total Reflectance-FTIR, Molecular Imprinted Polymer Sensor, Dendrimer-based Antibody Assays, Pyrolysis-GC-ion mobility spectrometry, and surface enhanced Raman spectroscopy. Data are being developed to support downselect of technologies to be incorporated in breadboard build in FY03 with demonstration in FY04. Target transition is to Joint Chemical Biological Agent Water Monitor EMD in FY05. The program timeline is FY01-04.

Domestic Demonstration and Application Programs (DDAP)

Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism (PROTECT): DOE CBNP

The PROTECT program is focused on developing and deploying early CB agent detection, identification and warning (DI&W) systems for vulnerable, heavily populated civilian facilities such as subway systems and airports. The subway component has been accelerated and will be completed in FY02. Emphasis will then be increased in airport protection. The program timeline is FY00-FY04. The roadmap shows possible candidate R&D systems for transition into PROTECT to include APDS, Gene Chip Biosensor, Advanced Multi-Functional Biochip, Argonne MAGIChip, μ ChemLab, PY-GC/IMS and Optical Particle Classifier.

Biological Aerosol Sentry and Information System (BASIS): DOE CBNP

The BASIS program is focused on developing early DI&W systems for limited duration bio-agent aerosol monitoring during special events such as major sporting events and political conventions. BASIS has successfully demonstrated architectures for special events and wide area monitoring, including successful deployments at the 2002 Winter Olympics in Salt Lake City and in events after September 11, 2001. BASIS is being transitioned to DOE emergency operations, and the fundamental architectural elements are also being incorporated into the DTRA National BioDetection Initiative Testbed. The program timeline is FY00–02. The roadmap shows possible candidate R&D systems for transition into BASIS to include CBNP Nucleic Acid Based Assays.

Bioforensics: DOE CBNP

The purpose of the Bioforensics program is to transition DOE bioforensic capabilities from the laboratory into the hands of intended users: law enforcement, the judiciary, public health and national security. These capabilities consist of a spectrum of DNA-based techniques that will help the user address a number of bioforensic challenges such as recognizing and documenting a bioterrorist attack and distinguishing it from natural disease outbreak. The program timeline is FY01–04. The roadmap shows possible candidate R&D systems for transition into Bioforensics to include CBNP Nucleic Acid Based Assays.

Advanced Concept/Technology Demonstrations

Integrated Bio Det ATD (JBREWS): DoD CBDP

The Joint Program Office for Biological Defense is leveraging the benefits of the ACTD program to greatly accelerate the development of the next generation of remote/early warning systems (i.e., systems other than the LR-BSDS). This new generation of detectors is referred to as the Joint Biological Remote/Early Warning System (JBREWS). JPO-BD is managing a JBREWS ACTD that will address selected CINCs' needs, and will better refine our requirements and concepts regarding remote/early warning systems. The Rationale is based on CENTCOM and EUCOM requirements. JPO-BD is sponsoring a series of concept studies, including a Study Advisory Group (SAG) composed of CINC, Service and Joint NBC Defense Board representatives. This cooperative effort will define the requirements for the JBREWS ACTD. The ACTD formally started in FY98, with fielding of ACTD systems to selected CINCs around FY01. Lessons learned from the JBREWS ACTD will assist the SAG in developing/refining its requirements document for the JBREWS objective system. JBREWS objective system is expected to start fielding around FY03.

Restoration of Operations ACTD (RestOps): DoD CBDP

The Restorations of Operations Advanced Concept Technology Demonstration (ACTD) will demonstrate those actions taken before, during and after an attack to *protect against* and *immediately react* to the consequences of a CB attack. These actions aim to restore operating tempo (OPTEMPO) in the execution of the mission and in the movement of individuals and materiel to support combat operations at a fixed site. One goal of this ACTD is to generate improved chemical and biological warfare detection technologies in an effort to reduce vulnerabilities at a fixed site. Candidate technologies will be tested during Joint Chemical Field Trial testing at DPG and subsequently down-selected for further testing during the ACTD. The ACTD is currently scheduled for the Final Demonstration to occur in FY03, which will be followed by two years of residual support at Osan Airbase.

Contamination Avoidance at Seaports of Debarkation (CASPOD): DoD CBDP

Seaports of debarkation (SPODs) are recognized as critical assets for power projection and force deployment operations, making them attractive targets for exploitation. Unified Combatant Commanders have responsibility to defend SPODs against terrorist or other adversary

CB, Toxic Industrial Chemical (TIC), or Toxic Industrial Material (TIM) attacks/releases. The CASPOD ACTD will leverage work done in other projects (Seaport Protection Analysis (SPPA) project and the RestOps ACTD) to identify and provide technologies, capabilities and procedures that can be utilized prior to, during, or after an attack/release to mitigate effects on time phased force deployment data (TPFDD) flow. Operational concepts and TTPs to initiate and sustain CB and TIC/TIM defense operations at SPODs will be demonstrated. The force structure necessary to implement procedural and equipment requirements will be identified and refined. A resident/pre-positioned or rapidly transportable CB and TIC/TIM defense equipment and material packages needed for employment at SPODs will be developed and demonstrated. Strategic operational improvements/shortfalls for CASPOD contingencies will be identified. In addition, a forum, process and structure for addressing and modifying U.S., coalition and host nation policy issues will be provided. The ACTD demonstration phase is currently scheduled from FY02-04, with transition occurring in FY05-06.

LFADD: DoD CBDP

The purpose of the Large Frame Aircraft Decontamination Demonstration is to identify methods of decontamination sufficiently effective to clean contaminated aircraft and allow their timely return to full, unrestricted use in the US. This requirement goes well beyond any type of "operational decontamination" and is not envisioned to be done in-theater, but at some type of transload location. The demonstration is sponsored by PACOM and is scheduled for Q4FY02 at Eglin AFB. It will consist of evaluating large frame, military cargo aircraft chemical warfare agent decontaminants. The most effective procedure to use for each decontaminating material will be determined along with the necessary logistic support. Analytical methods that can be used in the field to determine residual aircraft contamination will also be determined. Collected data, assessments and conclusions may be used by the USAF in establishing tactics, techniques and procedures (TTPs) for decontaminating exterior and interior aircraft components. Data may also be used to facilitate the establishment of new policies regarding use of previously contaminated aircraft (PCA). LFADD is strictly focused on chemical contamination, not biological contamination. In those cases where an extrapolation can be made to biological contamination, results will be documented. The program timeline is FY01-02.

Chemical Combat Assessment System (CCAS) ACTD: DoD CBDP

The CP2 ACTD Chemical Combat Assessment System (CCAS) consists of a rapid, field-modification kit for the Predator RQ-1B Medium Altitude Endurance (MAE) UAV to perform chemical combat assessment missions to detect, identify, track, characterize and collect chemical effluent following counterforce strike missions. Predator modifications for the CCAS kit require removal of the Tactical Endurance Synthetic Aperture Radar (TESAR) payload, integration of the Predator Infrared Airborne Narrowband Hyperspectral Combat Assessor (PIRANHA), and installation of compatible Predator wings along with a dispenser sub-system for two Flight Inserted Detection Expendables for Reconnaissance (FINDER) mini-UAVs. PIRANHA is a Fourier Transform Infrared (FTIR) remote sensor. Each FINDER contains a Spectrometric Point Ionizing Detector Expendable/Recoverable (SPIDER) point sensor (consisting of two Ion Mobility Spectrometer (IMS) point sensors for redundancy) and an integrated sample collector. The FINDER mini-UAVs are carried into the target area attached to the Predator outboard wing hard points. Technologies considered in this ACTD consist of already fielded government technologies or COTS products. The ACTD is currently scheduled for Operational Demonstrations in Jan 03 and Mar 03. The ACTD ends in Q2FY03 and is followed by two years of residual support (four kits).

Biological Combat Assessment System (BCAS) ACTD: DoD CBDP

BCAS will provide capability to the warfighter to plan, execute and assess counterforce strikes against fixed Biological Warfare (BW) facilities. The system will detect, identify, track, characterize and collect BW aerosol agents released during counterforce strikes. The system will be capable of assessing the post-strike plume for BW agents of interest (bacteria, viruses and toxins including anthrax, plague and ricin) to address existing CINC requirements and AF MNS CAF 328-92. A phased approach will be employed to prototype and demonstrate incremental technologies. Each phase will deliver technologies with potential stand-alone capabilities to reduce program risk. Phase 1 will prototype, integrate and demonstrate the capability to collect BW agents from a post-strike plume. Phase 2 will prototype, integrate and demonstrate the capability to detect and identify BW agents using a point/contact detector/identifier. Phase 3 will develop, prototype, integrate and demonstrate the capability to detect BW agents using a stand-off sensor. Each phase will build upon the success of the previous phase with an integrated end product incorporating all technologies. The system will employ orthogonal technologies for detection and identification to provide an acceptably low false alarm rate. The current leading technologies for point detectors/identifiers are antibody-based and deoxyribonucleic acid (DNA) based identification systems. The state of the art for stand-off detection is limited to detecting the presence of biological constituents in the plume; stand-off identification of specific agents cannot be accomplished with current technologies. Technologies considered in this ACTD consist of already fielded government technologies or COTS products. The ACTD is anticipated to be a four-year program, initiating in FY03, ending in FY06 and having two years of residual support through the end of FY08. Technologies considered in this ACTD consist of already fielded government technologies or COTS products.

Domestic Chemical Assessment System (DCAS) ACTD: DoD CBDP

DCAS will detect, identify, track and characterize domestic releases of toxic chemicals. It is based on the current CCAS system architecture and will leverage prototyping and integration accomplishments from the CCAS. DCAS will consist of the following: one PIRANHA (Predator Infrared Airborne Narrowband Hyperspectral Combat Assessor) remote sensor, purchase of spares and ground support equipment and personnel; one Twin Otter aircraft with aircrew to host PIRANHA sensor; two SPIDERS (Spectrometric Point Ionizing Detector Expendable and Recoverable) point sensors, purchase of Ground Station, purchase of spares and personnel; and two FINDERS (Flight Inserted Detection Expendable for Reconnaissance) mini-UAVs and personnel. In the domestic role, DCAS will provide deterrence, indication and warning of release of chemical vapors in an urban environment. DCAS will be deployed to cover specific events or designated, high priority geographic areas with the capability of 24-hour sustained operations using contactor personnel. Technologies considered in this ACTD consist of already fielded government technologies or COTS products. Projected end-users include Homeland Security/Defense and National and Local Law Enforcement agencies. The ACTD is scheduled to initiate late in Jul 02 with system deployment by Jun 03.

Test/Validation

Critical Reagents Program (CRP): DoD CBDP

The CRP was created by the Joint Program Office for Biological Defense (JPO-BD) in order to ensure security and availability of standardized high quality antibodies, antigens and gene probes and primers for biological warfare detection systems. In addition, the CRP is responsible for the production of the HHA's, which are the identification components in many existing biological detection systems as well as DoD Biological Sampling kits. CRP timeline initiates at FY98 and has no termination. Both CBNP Nucleic Acid Based Assay and CBDP Reagent Development R&D programs are developing candidate reagents for the CRP.

Joint Field Trials (JFT): DoD CBDP

The purpose of the JPO-BD JFT program is to evaluate new and existing technologies for incorporation into biological defense programs. JPO-BD sponsors a JFT test once a year in which developers provide test items that are evaluated by analysis teams. Successful technologies are subsequently matured for integration into detection systems. Program timeline initiates in FY98 and has no termination. The majority of Sensor/System R&D program items take place in JFT testing at some time (see roadmap).

Within the JFT are the Joint Chemical Field Trials (JCFT). This testing is being sponsored by the Defense Threat Reduction Agency in an effort to facilitate the identification of technologies that will be utilized in the RestOps and CASPOD ACTDs. JCFT testing was held at WDTC, Dugway Proving Grounds, from 2QFY00 through 2QFY01. Once technologies have been technically evaluated in JCFT, they will subsequently be analyzed in operational testing for military utility. Successful technologies will be eligible for acquisition.

DNA Reagents Testing and Validation: DoD CBDP

This program is responsible for testing and validating DNA based assays and reagents that are developed in the DOE Nucleic Acid Based Assays Sensor /System R&D Program. The two programs together represent an effort that partially addresses the DOE Biological Foundation program. The roadmap indicates that products from the R&D program will be taking part in the DNA Reagent Testing and Validation process in 4QFY01, 1QFY03 and 1QFY04.

Miscellaneous Testing: DoD CBDP

This program identifies the possibility of various testing opportunities to take place when projects arise. There is no current specific target associated with this process. Testing occurs on an as needed basis.

Miscellaneous Testing: DOE CBNP

Like DoD, DOE's Miscellaneous Testing program, also provides test opportunities for projects as they arise. Examples include wind tunnel and ECBC testing.

Foreign Comparative Testing (FCT): DoD CBDP

The FCT Program is a key acquisition tool for the Department of Defense (DoD) to improve the readiness of the U.S. Armed Forces while strengthening defense relationships through international armaments cooperation. The Program allows earlier fielding of quality non-developmental foreign equipment while avoiding costly Research, Development, Test and Evaluation (RDT&E) expenditures.

Guidance*Areas for Capability Enhancement (ACEs): DoD CBDP*

The ACEs process was established by the Counterproliferation Program Review Committee (CPRC). This process defines priority areas where additional capabilities are needed to meet the challenges induced by NBC weapon proliferation and delivery. A detailed list of each ACE and its designated target area can be found in the CPRC Report on Activities and Programs for Countering Proliferation and NBC Terrorism. There is one ACE that addresses detection, identification, characterization and warning of CBW agents (ACE 1: Detection, Identification, Characterization, Location, Prediction and Warning of CW and BW agents); these point detection programs support that ACE. The ACEs timeline is unlimited.

Joint Future Operational Capabilities (JFOC): DoD CBDP

JFOC was established by the Joint Service Integration Group in an effort to identify and prioritize Joint User far-term future operational capabilities as expressed in the emerging Joint NBC Defense Concept. The overall intent is to provide enhanced user guidance to the Joint NBC Defense Science and Technology (S&T) community to assist in the NBC S&T program formulation and execution process. Prioritized Joint Future Operational Capabilities include:

- Contamination Avoidance⁷
- NBC Battle Management
- Collective Protection
- Restoration Capability
- Individual Protection

A detailed description of JFOC can be found in the NBC Defense Annual Report. The JFOC timeline is unlimited.

CB Detection and Identification: Current Programs and Projects

Sensor/System R&D programs include CB Point detection and Identification, Reagents/Assay development, and Supporting Technologies. Biological Point Detection and Identification Programs are further subdivided into major activity areas: Genetic Detection, Detector on a Chip, Mass Spectrometry and other programs that have not yet been categorized.

Genetic Detection

Autonomous Pathogen Detection System (APDS): DOE CBNP

The LLNL APDS is a stand-alone instrument designed to provide automated, continuous monitoring of aerosols for detection and identification of potential biological agents. Major components include an aerosol collector, sample preparation module, flow cytometer, and Polymerase Chain Reaction (PCR) thermocycler. The system is presently being designed to utilize a combination of both multiplex immuno based flow cytometer and genetic recognition (via PCR) assays. The current goal is to complete a fieldable prototype with immunoassays only in FY02, adding the PCR component in FY04. The roadmap shows transition opportunities for APDS to include the PROTECT sensor testbed in FY04.

Bio Sample Prep System DTO-PCR (BSPS): DoD CBDP

The ECBC BSPS is an automated sample processing system that has the capability to lyse and process spores, bacteria and virus samples. Lysis methodology is still being optimized, however, down select processes have shown the Cepheid bead-based ultra-sonication to be the current method of choice for the genetic platform. The processed sample is characterized by a Taqman-based PCR. Nucleic acid detection reagents against eight bacterial and viral agents are in development. The roadmap shows transition opportunities for BSPS-PCR to include JBPDS in FY02.

Handheld Advanced Nucleic Acid Analyzer (HANAA): DOE/LLNL

The objective of this project is to develop an advanced technology for the detection of biological warfare agents. The HANAA analyzes biological samples for the presence of specific DNA sequences. The HANAA operation is based on the detection of Taqman fluorphors from DNA products generated during the polymerase chain reaction (PCR). Taqman PCR uses special fluorescent probes attached to the replicated DNA to provide real-time detection. The HANAA

⁷ Point and Standoff Detection are included within the JFOC definition of Contamination Avoidance.

provides a man-portable, handheld, field-worthy PCR bio-detection instrument. It is ideally suited for emergency response where biological pathogens are suspected and for field monitoring where portability and fast answers are critical. It can also be used in intelligence, combat or reconnaissance missions. Current commercialization efforts involve building a small number of evaluation instruments by the end of this year. The roadmap shows that instruments will be for sale in June 2002.

Detector on a Chip

Gene Chip Biosensor: DoD CBDP

The Gene Chip Biosensor, under development at ECBC, objectives are to first individually develop and then to demonstrate proof-of-principle integration of two DNA technologies that will offer an enhanced capability over current methods to detect and identify bacterial and viral bioagents, at the strain level, in samples of unknown composition. The two technologies are "universal" PCR amplification and DNA Microarray ("gene chip") analysis. The PCR will use a "universal" random primer set and fluorophore-nucleotide conjugates to amplify and label all DNA present in a sample. Species and strain-level identification of the amplified genetic material will be carried out through the use of a DNA microarray. This work will also begin to integrate the two technologies for use in a complete DNA detector. The roadmap shows transition opportunities for the Gene Chip Biosensor to include the PROTECT sensor testbed in FY04.

Advanced Multi-Function Biochip (AMB): DOE CBNP

The AMB is a fully integrated fluorescence based microelectronic device developed by ORNL in collaboration with Becton Dickinson and Honeywell. AMB capabilities include bioassay multiplexing generated by engineering different types (DNA, antibody, enzyme) of bio-receptors on the same chip. Genetic and immunologic assay systems include Strand Displacement Amplification (SDA) and Enzyme-Linked Immunosorbent Assay (ELISA) methodologies, respectively. Aerosol collection and sample processing will be provided by mesopump and ultrasound based technologies. The roadmap shows transition opportunities for AMB to include the PROTECT sensor testbed and JCBAWM in FY04.

Argonne MAGIChip: DoD DARPA

The Argonne MAGIChip is a microchip sensor being developed for the identification of pathogenic organisms. MAGIChip biomolecular reactions take place in a polyacrylamide gel matrix that provides a controllable, 3-D liquid phase environment in which multiple analysis may be performed. MAGIChip capabilities include identification of both RNA and DNA targets, toxin proteins, strain mutations, PCR amplification and distinguishing between alive and dead organisms. The chips can be regenerated and used several times. This technology is easily amenable to automation. The roadmap shows transition opportunities for the MAGIChip to include the PROTECT sensor testbed in FY04.

Activity Based Detection and Diagnostics: DoD DARPA

This program is being developed to demonstrate that living cells and tissues can be engineered to detect biological and chemical threats. These cell/tissue based biosensor systems could potentially provide dramatic new capabilities for sensing the activity of existing, emerging and engineered biological and chemical warfare threats or hazards. The approach is to extract cell/tissue agent response signatures from living systems and ultimately put these signatures on a chip platform. The roadmap shows transition opportunities for this technology to include the PROTECT sensor testbed and JCBAWM in FY04.

Mass Spectrometry

Bio Time of Flight Mass Spectrometer: DoD DARPA

The Bio-TOF MS is being developed for the detection of aerosolized bio-agents, including bacteria, virus and toxin threats. It utilizes a unique sample ionization process called Matrix Assisted Laser Desorption Ionization. The mass spectrometer is a miniature time-of-flight instrument (TOF). The Bio-TOF is designed for completely automated aerosol collection, processing and identification of threats (See Appendix B for more details). Key accomplishments to date include completion of an extensive signature collection of both threats and interferents on laboratory instruments and data collection and performance evaluation on anthrax simulant Bg. The roadmap shows transition opportunities for this technology to include JBPDS in FY02 and JSMCBD in FY08.

Bio Sample Prep System DTO-ESI/MS (BSPS): DoD CBDP

The BSPS is an automated sample processing system that has the capability to lyse and process spores, bacteria and virus samples. Biomarkers from the sample are separated by high performance liquid chromatography (HPLC) and subsequently subjected to electrospray ionization mass spectrometry. Protein mass spectral databases against eight bacterial and viral agents are in development. The roadmap shows transition opportunities for this technology to include JBPDS in FY02.

Advanced Ion Trap Mass Spectrometer: DOE CBNP

ORNL is developing a mass spectrometer system that will provide for simultaneous detection and identification of bio-agent protein targets. Proteins were the target of choice due to their ubiquitous nature in each biological threat category: bacteria, virus and toxin. The technique utilizes an electrospray/Ion-Ion chemistry process that facilitates mass spectrometric analysis of proteins. This program was not funded after FY01 due to competing priorities for resources.

Science and Engineering Services Incorporated (SESI) Infrared Mass Spectrometer: DoD DARPA

The SESI mass spectrometer was uniquely designed to identify biological agents. The system utilizes an infrared and ultraviolet laser desorption ionization process for sample ionization. This process generates more signature masses than conventional ionization methods, which provides a higher level of certainty in bioagent identification. This is an important capability, especially when considering spore forming bacteria. This project was funded only through the end of FY00.

Handheld Systems

μChemLab/CB: DOE CBNP (SNL)

The objective of this project is to develop a fully self-contained, user friendly, hand-held unit for the detection and analysis of the full range of chemical and biological threats. Intended users include first responders as well as fixed and mobile monitoring networks. The technical approach utilizes micro-machined chips that contain parallel and serial micro-separation columns/channels. The μChemLab/CB currently exists as two separate systems, one for chemical agent detection and the other for biological agent detection. The biological system utilizes micro-scale, liquid phase chromatography and capillary electrophoresis together with laser-induced fluorescence (LIF) detection to provide sensitive analyses at low nanomolar concentration levels. The chemical system utilizes cascading of sample preconcentration, gas chromatography separation and surface acoustic wave (SAW) detection to provide high sensitivity and chemically selective detection. Performance goals are at ppb sensitivity for nerve agents and 10 ppb for blister agents with a detection time of 1 minute. Late FY00 live agent testing of the CW research prototype at ECBC demonstrated excellent performance against a range of nerve and blister

agents in the presence or absence of realistic interferents. Other roadmap and milestone events include: CW prototype testing in PROTECT DDAP in FY01; demonstration of CW/TIC research prototype in FY03; and completion of CW/TIC engineering prototype for use in field trials by FY04. Transition opportunities for μ ChemLab/CW and μ ChemLab/BW individual systems include the PROTECT sensor test bed in FY02 and FY04. In addition, both chemical and biological detection capabilities are scheduled to be integrated into the same system by FY04. Transition opportunities for the integrated CB system include JCBAWM and JSMCBD in FY08.

Personal Alarm Monitor: TSWG/CBRNC

The Personal Alarm Monitor develops and tests a prototype system for warning of the individual of exposure to selected chemical agents in sufficient time to escape or don respiratory protection. The initial focus for phase I is nerve agents. Phase II will focus on biological agents, initially anthrax. The phase II product will be a biological agent warning badge designed to be read/developed at the end of the work shift to expedite treatment in the case of exposure. An initial chemical, visual alert badge prototype has been completed and the design is currently being modified to incorporate an electronic alert. Intended users for these products include Civilian law enforcement and other emergency responders. The program was initiated in FY 00 and final chemical and biological prototypes are scheduled for completion at the end of FY02. Transition into the commercial sector is scheduled for FY04.

Handheld Low-level Chemical Agent Detector: TSWG/CBRNC

The Handheld Low-level Chemical Agent Detector project will provide ten prototype chemical detector systems capable of detecting a wide range of chemicals, both industrial chemicals and military agents, at concentrations heretofore not achievable in the field in a handheld device. It will be capable of reliable detection at levels below the required immediately dangerous to life and health (IDLH) and desired time weighted average (TWA). The two-column gas chromatography system shall minimize development risk by miniaturizing and integrating existing benchtop and field capabilities in a battery powered package capable of operating for about eight hours using ambient air as the carrier gas. Using efficient thermal conductivity detectors, the system shall reliably detect and quantify threat chemicals at less than 10 ppb levels. While adequate for most toxic industrial chemicals and some military agents, special sorbent trap and rapid desorption sample concentration methods may be required to measure VX, mustard agents and lewisite. These chemical weapon agents (CWA) have IDLHs less than 2 ppb. Another key technical issue is efficient power management. Intended users for this system include the Technical Escort Unit and Civilian HAZMAT Units. The program was initiated in Q2FY01 and is scheduled for prototype delivery by March 2002. Transition into the commercial sector is scheduled for FY03.

SMALLCAD: TSWG/CBRNC

The SMALLCAD chemical agent detector project integrates two mature chemical detection technologies, ion mobility spectroscopy (IMS) and surface acoustic wave (SAW). The system utilizes a two channel auctioning algorithm to dramatically reduce the false positive rate. Fusing the outputs from two orthogonal detection systems has already been accomplished and demonstrated dramatic reduction in the false alarm rate during the TSWG funded Urban Chemical Release Detection project. To meet operational requirements, Small CAD will use miniaturized detectors. The reduction in detector size has already been accomplished by the subcontractors and tested. Two technical issues currently being addressed include refinement and testing of the sensor fusion algorithm to minimize false negative response and power management. The intended user for the SMALLCAD is Special Operations Forces (SOF). The program was initiated in Q4FY00 and is scheduled for prototype completion in April 2002. The

SMALLCAD bench-scale prototype has been tested at TNO Netherlands in June 2001 and results are pending. Transition into the commercial sector is scheduled for FY03.

Chemical Agent Detection Badges: DOE (LANL)

Chemical Agent Detection Badges (CADB) are being developed to provide detection of air and waterborne chemical warfare agents. A miniature, lightweight (<8 oz.), self-contained, battery powered sensor for the detection and identification of chemical agents is the goal of this effort. The prototype CW sensing devices will consist of replaceable electrochemical sensors together with batteries, pump or fan, and measurement electronics. Potential user applications include: a 'film badge' or 'pager' for warning of the presence of chemical agents; a remotely monitored, unattended package with integrated telemetry; a base technology for electrochemical decontamination; a patch for probing breakthrough of agents across a protective clothing barrier. The system may also be potentially adaptable to some biological agents. A review of the Roadmap shows two key milestones. Q4FY01 testing will demonstrate response of a stand-alone prototype device to 3 chemical warfare agents and 2 domestic chemical targets at ppm levels. Q4FY02 testing will demonstrate response of a stand-alone prototype to airborne chemicals at sub-ppm levels. Intended users include first responders as well as fixed and mobile monitoring networks.

Other

Up-Converting Phosphor Flow Cytometer (UCPFCM): DoD DARPA

The SRI UCPFCM is a compact UCP diode laser-based flow cytometer being developed to detect biological agents and meet detection requirements for JBPDS Block II. Because there are many spectrally unique phosphors activated by the same energy, this system has the ability of multiplexing. Further supporting the use of UCP technology is that UCP compounds are easily detected in dirty environments which provides for a highly sensitive, low false alarm rate system.

Up-Converting Phosphor Handheld Assay (UCPHHA): DoD DARPA

The SRI UCPHHA utilizes the same UCP technology as the UCPFCM. The primary objective of this project is to evaluate UCP technology in the U.S. Government standard handheld assay (HHA) format using Government Furnished Equipment (GFE) antibodies. A secondary objective is to develop a hardened handheld biosensor that incorporates UCP based HHA strips for field operation. Research is already underway in modifying the standard HHA with UCP technology. A Multi-target Lateral Flow Wick Assay has been developed that has demonstrated multiple target identification in the same assay.

Immunobead Force Differentiation Assay (FDA): DoD CDBP

The FDA, under development at the Naval Research Laboratory (NRL), is a highly specific and sensitive biosensor capable of measuring antibody-antigen bond forces using magnetic immunobeads. Goals include identifying bacteria, viruses and toxins with 1 ACPLA sensitivity and greater than 99% specificity in less than 15 minutes. Transition opportunities for this technology include JBPDS in FY02.

Pyrolysis-Gas Chromatography/Ion Mobility Spectrometry (PY-GC/IMS): DoD CDBP

The PY-GC/IMS is a sensor being developed for both chemical and biological detection. The effort examines the potential for discriminating biological materials at a level of classification higher than "bio" versus "non-bio". This is accomplished by GC/IMS analysis of chemical markers produced upon pyrolysis of biological materials. IMS is already employed in fielded detectors for chemical agents. Transition opportunities for this technology include JBPDS in FY03, PROTECT in FY04 and JSMCBD in FY07.

Optical Particle Classifier: DoD CBDP

The Optical Particle Classifier, under development at NRL, is an effort to improve the performance of optical trigger systems. This will be accomplished through exploration of optical parameters, including angular elastic scattering, in addition to fluorescence to differentiate biological particles from other materials that fluoresce. Key parameters being evaluated are particle size and shape as well as fluorescence on individual particles. Transition opportunities for this technology include JBPDS in FY02, PROTECT in FY04, and JSMCBD in FY07.

Networked Terrorism Detection System (AFP): NIJ, Oklahoma City Memorial Institute for the Prevention of Terrorism

The overall goal of Networked Terrorism Detection System is to develop highly specific approaches for detecting and identifying explosives, nerve gases and BW agents. This development will be applied to produce a continuous, real time network detection system for use against terrorist threats. The approach is based upon utilization of a unique amplifying fluorescent polymer (AFP), which will greatly increase the speed and sensitivity of detecting explosives and CBW agents. The process will focus on producing AFPs that are activated with probes designed for detection of explosives and specific CBW agents. This process will be tested for nitroaromatic and other explosives, a nerve gas agent and three BW agents. The activated AFPs will be incorporated into microarray sensors, which can be integrated into network systems, such as General Atomics E-Smart[®], providing continuous monitoring of high value buildings or complexes. Key technology development issues include activation of AFP with chromophore, oligonucleotide and antibody probes in correct chemical and geometric orientation to ensure binding events are transduced to AFP. A prototype microarray sensor is scheduled for Q1FY04. The sensor is envisioned to consist of a complex field of polymer "wells" to which samples will be delivered. Each well will contain a thin film of polymer activated with a specific probe for a particular explosive or CBW agent. Probes Projected end user is the Air Force E-SMART project. This technology is scheduled to transition into the commercial sector in FY04.

Integrated CIB Point Detectors: DoD CBDP

The longer-term goal of the detection program is to provide technology solutions that decrease the number of individual detectors in the inventory, hence, decreasing the logistics burden associated with maintenance, training and multiple operational concepts. It is also desirable to decrease size and cost of CB detectors. This thrust focuses on conceptualization, development and validation of technologies that provide small, lower cost, point detectors/identifiers that simultaneously address both chemical and biological threats. Transition opportunities include JSMCBD in FY07. JFOCs addressed include Contamination Avoidance-Bio Early Warning (CA-BE), Contamination Avoidance-Bio Point Detection (CA-BP), Contamination Avoidance-Chem Early Warning (CA-CE), and Contamination Avoidance-Chem Point Detection (CA-CP).

CIB Identification in Food/Water: DoD CBDP

The primary thrust in this area is the development of concepts/technologies to detect and identify contaminants in food and potable water. The traditional threat to the warfighter has been respiratory or percutaneous exposure to CBW agents, but with the change in global politics the threat has expanded to include force protection issues as well as the traditional battle/collateral damage problems. Transition opportunities include JCBAWM in FY07. The JFOC addressed is Contamination Avoidance-Medical Surveillance/Vet Spt (CA-MV).

Reagents/Assay Development

Reagent Development (Antibodies and Alternatives): DoD CBDP

The purpose of this thrust is to develop new methodology to either greatly enhance the existing set of reagents that would impact, by at least an order of magnitude, the overall system performance (cost, logistical burden, etc.) or to develop reagents that cannot be produced via the current set of available methodologies. The goal is to expand the current set of fielded capabilities in biological detection/identification to address the full threat list. Targeted mature development programs are JBPDS Blk II and Critical Reagents Program (CRP). This effort is being performed by a number of laboratories. One primary focus is to explore and utilize genetic recombinant techniques for the production of specific antigen-binding antibody fragments to antigens of high priority in biological defense. Research on multivalent assays is also ongoing. Biased libraries, generated from immunized animals, or unbiased random combinatorial libraries serve as the principal supply of antibody clones. At present, the major focus is on biased libraries. Candidate recombinant antibody fragments are implemented in ELISA, HHA and other immuno-biosensor platforms for comparison of efficacy with established reagents. Candidates showing high potential are submitted to the CRP for validation and employment in fielded sensors. Ongoing efforts in this program are taking place at a number of locations including ECBC and NMRC. The JFOC addressed is Contamination Avoidance-Bio Point Detection (CA-BP).

Nucleic Acid Based Assays: DOE CBNP

This R&D effort is part of the DOE Biological Foundations program. The overall objective of Biological Foundations is to provide an integrated body of biological information and tools as a foundation for CBNP. Expected nucleic acid based capabilities generated from these programs include:

- Development of tools and methods for rapidly identifying and isolating unique DNA in an organism to, over time, reduce the cost and time of signature development by more than a factor of 100
- Production of whole-genome DNA sequence data for key pathogens and their nearest neighbors as a resource for signature development
- Development of informatics tools to facilitate the development, sharing, utilization and archiving of pathogen DNA sequence signatures

Nucleic Acid Based Assays developed in this program will be subsequently tested in the DNA Reagents testing and Validation, Critical Reagents, BASIS and Bioforensics Acquisition/Transition Activity programs.

Bio-contaminant Detection and Identification Strategies: TSWG/CBRNC

Monitoring to detect the presence of purposefully released bio-contaminants requires an established monitoring protocol for use in non-battlefield scenarios. This research compares sample collection and sample preparation strategies, and develops a monitoring protocol for quantitative assay for the detection of three biocontaminant simulants in the air and on a variety of common office surface materials. Technical obstacles include reduction of test chamber sampling results to simple "rules of thumb" analogous to those used in radiological controls surface sampling. Intended users include the military and civilian response personnel. The program was initiated in FY00 and Sampling Guidelines are scheduled to be commercially available by the end of FY02.

Supporting Technologies

Ambient Background Characterization: DoD CBDP-DOE CBNP

Ambient background characterization is an effort to collect representative background samples as well as to develop a set of heuristics describing the background that may be encountered by detectors in field application. The project is a joint CBDP-CBNP task in collaboration with The Technical Cooperation Program (TTCP) member countries and leverages the prior collection of background data from various sites around the world by a number of programs. The project is scheduled as a two-year effort completing in FY01 with planned follow-on to collect additional data to fill identified gaps.

Aerosol Samplers: DoD CBDP / DOE⁸

Basic aerosol technology provides a capability to generate and characterize standard test aerosols and CB simulant aerosols in the field and in laboratory facilities—including chambers and wind tunnels. This aspect of the aerosol technology program is focused on quantitative analyses of aerosols to provide the contamination avoidance commodity area with systematic quantification of developmental aerosol collectors and their inlets, in order to accelerate the hardware development process. It also provides well characterized aerosol challenges to support standoff detection development. Near-term investments are being implemented in a wind tunnel capability for a wide range of challenge aerosols at speeds up to 60 mph. A second area of emphasis is aerosol collector technology. This includes the design of improved aerosol inlets processing elements such as ducts, concentrators and size-selective devices (*e.g.*, impactors and cyclones), and collection devices for the aerosol particles. Transition opportunities for these technologies include JBPDS and JSMCBD.

Threat Agent Characterization: DoD CBDP

Investments are being made in the characterization of the properties of threat agents. Emphasis is also placed on developing appropriate simulants for use in the RDT&E process. Execution and funding of the work are integrated across Non-Medical, Medical and DOE performers and coordinated with the Intelligence Community. Deliverables from this program are technical data on threat agents and simulants for developmental and operational testing.

Threat Agent Characterization: DoD CBNP

In order to improve detection, identification and forensics capabilities, CBNP has begun large collections of several strains of threat pathogens. The *B. anthracis* strain collection is among the world's largest. The program has initiated collaborations with USAMRIID, Rocky Mountain Laboratories, the CDC and British laboratories to expand the collections of strains and closely related organisms.

⁸ DOE funding not included in the CBNP budget.

APPENDIX B

Acquisition/Transition Activities Involving CB Decontamination Technologies

The transition and acquisition activities to which CB decontamination research and development programs and DoD and DOE make significant contributions are introduced below. They include six EMDs (JSFDS, JSSED, Superior Decon System, Next Generation Decon Kit, Sorbent Decon System, Modular Decon System), three ACTD/ATDs (RestOps, CASPOD, LFADD), and several types of testing and validation programs. Also, a Crisis Deployment/Special Events section was added to document the use of technologies in real-world, crisis situations. The DoD activities, as well as the supporting R&D programs, contribute to requirements developed in two key pieces of guidance: the Joint Field Operational Capabilities (JFOCs) list and the Areas for Capability Enhancement (ACEs) identified as necessary to the achievement of the JFOCs.

Joint Service Family of Decon Systems (JSFDS): DoD CBDP

The purpose of this program is to develop a family of CB decontamination systems and application systems for both equipment and wounded personnel. Block I will evaluate, review and test NDI, COTS and mature technology decontaminants, and will field those that meet the requirements of the Joint Operational Requirements Document (JORD) for use at fixed facilities, ports of entry, airfields, logistics nodes and key command and control centers. Block II will develop a family of decontaminant applicator subsystems that will be capable of dispensing the selected family of decontaminants. Block III will develop decontaminants and applicators for skin/casualties with open wounds. The program timeline for Blocks I-III is FY01-11. The roadmap shows possible candidate R&D technologies for transition into JSFDS to include DF-100/200 and DoD Solution Chemistry technologies.

Joint Service Sensitive Equipment Decontamination Program (JSSED): DoD CBDP

The purpose of this program is to develop CB decontamination systems which can be utilized on small equipment items and interior spaces. Block I will develop decon systems that can decontaminate small equipment items, electronics, optics or components that may be easily damaged by current decontamination methods. Block II will develop the capability to decon interior spaces such as the interior of aircraft, ships, vehicles and mobile communication stations, all of which contain a multitude of surfaces and electronic components. Block III will focus on decontamination of Phase II interiors while on the move. The program timeline for Blocks I-III is FY01-11. The roadmap shows possible candidate R&D technologies for transition into JSSED to include Environmentally Friendly Solvents, Destructive Adsorption, Supercritical CO₂, APPJ and DoD Plasma.

Superior Decon System: DoD CBDP

The purpose of this program is to develop a single, multi-use organic, aqueous-based or mixed organic/aqueous decontamination solution to replace DS2 and aqueous bleach (STB and HTH) in thorough decontamination applications. Applicator systems will be developed for use by mobile forces that are capable of dispensing the new decontaminating solution. The program timeline is FY06-11. The roadmap shows possible candidate R&D technologies for transition into Superior Decon System to include DoD Enzyme Decon technologies, L-gel and L-gel-based Solid Water and DoD Oxidative Formulations technologies.

Next Generation Decon Kit: DoD CBDP

The purpose of this program is to develop a solids-based decon system for use in immediate and operational decon operations. This kit is a follow on sorbent program that will have greater reactivity than the Sorbent Decon System and will be effective against both chemical and biological agents. The program timeline is FY08–11. The roadmap shows possible candidate R&D technologies for transition into Next Generation Decon Kit to include technologies from Destructive Adsorption.

Sorbent Decon System: DoD CBDP

The purpose of this program is to develop an immediate decontaminant that is superior to the XE555 carboneous and ion exchange resin mix previously used in the M295 kit. The new adsorbent eliminates DS–2 from the operator's spraydown procedures. The key requirements for the sorbent are a reduction in off-gassing and contact hazard associated with the adsorbent after use, when compared to the M295 kit. The program timeline terminated at the end of FY01.

Modular Decon System: DoD CBDP

The Modular Decontamination System (MDS) program was initiated to provide the soldier with a vastly improved capability to perform detailed equipment decontamination on the battlefield. The Army's experience during Operation Desert Storm validated the need for a more deployable system and for more efficient use of water, a scarce resource in an arid environment. The M22 High Pressure Washer (HPW) delivers hot pressurized water up to 3,000 psi at a rate of 5 gpm through two spray wands. This washer can also dispense a high-volume (40 gpm) flow of cold water and, through an injector, liquid detergents. Its accessories include the necessary hoses, wands, nozzles, hydrant adapters and injector. The M22 high-pressure/hot water module can draw water from natural water sources and dispense it at variable adjustable pressures, temperatures and flow rates. The hydrant adapters provide a capability for using urban water supplies and it can also be operated from a trailer. The program timeline is active into FY02. The first equipped unit is scheduled for FY02 and initial operational capability is scheduled for FY03.

Domestic Demonstration and Application Programs***Program for Response Options and Technology Enhancements for CB Terrorism (PROTECT): DOE CBNP***

Special requirements for decontamination and restoration of subway service after a chemical incident have emerged from discussions with the Washington, D.C. and Boston subway staffs. Contacts with the National Medical Response Teams (NMRTs) have led to discussions of subway needs versus NMRT chemical agent decontamination capabilities. This information is also being coordinated with CBNP decontamination researchers. Decontamination plans for the subway systems have evolved considerably, with only a few technical and administrative issues remaining. Negotiations are underway to include decontamination technologies in PROTECT demonstrations. The program timeline for PROTECT is FY00–04.

Advanced Concept Technology Demonstrations***Restoration of Operations (RestOps): DoD CBDP***

The Restorations of Operations Advanced Concept Technology Demonstration (ACTD) will demonstrate those actions taken before, during and after an attack to *protect against* and *immediately react* to the consequences of a CB attack. These actions aim to restore operating tempo (OPTEMPO) in the execution of the mission and in the movement of individuals and materiel to support combat operations at a fixed site. One goal of this ACTD is to generate improved chemical and biological warfare detection technologies in an effort to reduce vulnerabilities at a fixed site. Candidate technologies will be tested during Joint Chemical Field Trial testing at DPG and subsequently down-selected for further testing during the ACTD. In

addition to providing technology transition opportunities for CB detection, Protection and Medical commodity areas, RestOps also offers prospects for Decontamination technology transition. RestOps decontamination testing was executed in the Joint Chemical Field Trials (JCFT) during FY00 and FY01. The roadmap shows possible candidate R&D technologies for transition into RestOps to include DF-100/200 and L-gel. The ACTD is currently scheduled to end at the end of FY03 followed by two years of residual support at Osan Airbase.

Contamination Avoidance at Seaports of Debarkation (CASPOD): DoD CDBP

Seaports of debarkation (SPODs) are recognized as critical assets for power projection and force deployment operations, making them attractive targets for exploitation. Unified Combatant Commanders have responsibility to defend SPODs against terrorist or other adversary CB, Toxic Industrial Chemical (TIC) or Toxic Industrial Material (TIM) attacks/releases. The CASPOD ACTD will leverage work done in other projects (Seaport Protection Analysis (SPPA) project and the RestOps ACTD) to identify and provide technologies, capabilities and procedures that can be utilized prior to, during or after an attack/release to mitigate effects on time phased force deployment data (TPFDD) flow. Operational concepts and TTPs to initiate and sustain CB and TIC/TIM defense operations at SPODs will be demonstrated. The force structure necessary to implement procedural and equipment requirements will be identified and refined. A resident/pre-positioned or rapidly transportable CB and TIC/TIM defense equipment and material packages needed for employment at SPODs will be developed and demonstrated. Strategic operational improvements/shortfalls for CASPOD contingencies will be identified. In addition, a forum, process and structure for addressing and modifying U.S., coalition and host nation policy issues will be provided. The ACTD demonstration phase is currently scheduled from FY02-04, with transition occurring in FY05-06. The roadmap shows possible candidate R&D technologies for transition into CASPOD to include DF-100/200, L-gel and Decon Green.

LFADD: DoD CDBP

The purpose of the Large Frame Aircraft Decontamination Demonstration is to identify methods of decontamination sufficiently effective to clean contaminated aircraft and allow their timely return to full, unrestricted use in the US. This requirement goes well beyond any type of "operational decontamination" and is not envisioned to be done in-theater, but at some type of transload location. The demonstration is sponsored by PACOM and is scheduled for FY02 at Eglin AFB. It will consist of evaluating large frame, military cargo aircraft chemical warfare agent decontaminants. The most effective procedure to use for each decontaminating material will be determined along with the necessary logistic support. Analytical methods that can be used in the field to determine residual aircraft contamination will also be determined. Data collected, assessments and conclusions may be used by the USAF in establishing tactics, techniques and procedures (TTPs) for decontaminating exterior and interior aircraft components. Data may also be used to facilitate the establishment of new policies regarding use of previously contaminated aircraft (PCA). LFADD is strictly focused on chemical contamination rather than biological contamination. In those cases where an extrapolation can be made to biological contamination, results will be documented. Roadmap technologies tested for inclusion in LFADD were Sandia Foam (DF-100/200) and Environmentally Friendly Solvents.

Test/Validation

Miscellaneous Testing: DoD CDBP

This program identifies the possibility of various decontamination testing opportunities to take place when projects arise. There is no current specific target associated with this process. Testing occurs on an as needed basis. The roadmap shows R&D technologies tested in this program to include DoD Enzyme Decon, Environmentally Friendly Solvents, Decon Green, Destructive Adsorption, Plasma and Supercritical CO₂.

Miscellaneous Testing: DOE CBNP

Like DoD, DOE's Miscellaneous Testing program also provides test opportunities for decontamination projects as they arise, such as ECBC testing.

Decontamination Field Trials: DOE CBNP

These trials are focused on the bio-decontamination of office materials that have been contaminated with bacteria. They have been separated into three areas, Phase I, Phase I Follow on and Phase II. Phase I testing involved a number of candidate technologies that were tested for bio-decontamination utility on office materials. Testing was executed at Dugway Proving Ground in FY99. Phase I follow on testing will evaluate ten additional technologies that have been identified with potential bio-decontamination applicability. Testing is scheduled for FY02 and will utilize the original Phase I panel test format to evaluate the efficacy of these additional technologies. This testing format consists of 16x16 inch panels made from typical office materials such as ceiling tile and carpet. Panels are contaminated with *Bacillus globigii* bacteria spores, allowed to equilibrate and then decontaminated using the candidate technologies. Evaluation is made based on the technologies' ability to reduce the spore residual to less than or equal to 500 spores per square meter. This test format allows a direct comparison of bio-decontamination technologies. Phase II testing in FY01 investigated the bio-decontamination of office materials, with an operational rather than technical approach.

Guidance**Areas for Capability Enhancement (ACEs): DoD CBDP**

The ACEs process was established by the Counterproliferation Program Review Committee (CPRC). This process defines priority areas where additional capabilities are needed to meet the challenges induced by NBC weapon proliferation and delivery. A detailed list of each ACE and its designated target area can be found in the CPRC Report on Activities and Programs for Countering Proliferation and NBC Terrorism. There is one ACE that addresses decontamination (ACE 2: Enable sustained operations in an NBC environment through decontamination, and individual and collective protection); these programs support that ACE. The ACEs timeline is unlimited.

Joint Future Operational Capabilities (JFOC): DoD CBDP

JFOC was established by the Joint Service Integration Group in an effort to identify and prioritize Joint User far-term future operational capabilities as expressed in the emerging Joint NBC Defense Concept. The overall intent is to provide enhanced user guidance to the Joint NBC Defense Science and Technology (S&T) community to assist in the NBC S&T program formulation and execution process. Prioritized Joint Future Operational Capabilities include:

- Contamination Avoidance
- NBC Battle Management
- Collective Protection
- Restoration Capability⁹
- Individual Protection

A detailed description of JFOC can be found in the NBC Defense Annual Report. The JFOC timeline is unlimited. (Note that Point and Standoff Detection are included within the JFOC definition of Contamination Avoidance.)

⁹ Decontamination is included within the JFOC definition of Restoration Capability.

Chem-Bio Decontamination: Current Programs and Projects

Solution Phase Chemistry

The goal of this thrust area is to develop decon systems that supplement or replace existing systems used for immediate, operational and thorough decontamination against both chemical and biological agents. Organic or aqueous-based decontamination solutions will be developed to replace DS-2 and aqueous bleach in applications by identifying, stabilizing and optimizing the chemistry of candidate systems, and by developing means to reduce logistical burdens associated with the operational decontamination. Emphasis areas include enzymatic and catalytic chemistry, oxidative chemistry and formulation development. Leveraging efforts include Sandia foam, L-gel, Maxygen enzymatic biological formulation and the University of Michigan nanoemulsion.

Environmentally Friendly Solvents: DoD CBDP

The objective of this program is to develop the ability to successfully decontaminate sensitive equipment without adversely affecting its operational readiness, reliability or maintainability. In the mid-1990s new, non-ODC substitute solvents were perfected and marketed. Paralleling the development of the new solvents were major advances in the field of precision cleaning equipment. This project is exploiting the progress made in solvent chemistry and precision cleaning hardware for sensitive item decontamination. In addition, a spot decon system using these solvents with suspended metal oxides will also be explored. The roadmap shows transition opportunities for this technology to include JSSED (Blk I) and LFADD in FY02, and JSSED (Blk II/III) in FY04.

Enzyme Decon (Chemical): DoD CBDP

The objective of DTO CB.09 is to develop an enzyme-based, chemical-only catalytic decontaminant that will be non-toxic, non-corrosive and environmentally safe. The decontaminant will consist of a variety of enzymes, chemical catalysts or reactants and stabilizing materials (buffers, etc.). It will be packaged in a dried form and easily reconstituted with any available water. It will be disseminated with currently available or planned decontamination systems, fire-fighting equipment or other types of sprayers (e.g. aircraft deicing equipment or washracks). The decontaminant is intended for use in all situations where some water can be tolerated, from small-scale operations (personnel and personal equipment) to operational vehicles and equipment to large-scale fixed sites (airbases, ports, logistics nodes and civilian areas). Other efforts outside of the DTO include enhancing and broadening the catalytic properties of the wild-type enzyme phosphotriesterase (PTE) to improve hydrolytic detoxification and detection of the G- and V-type nerve agents and their associated analogs. In addition, efforts are underway to find enzymes capable of hydrolytic detoxification of GV and other less common agents. The roadmap shows transition opportunities for this technology to include the Superior Decon System in FY06.

Enzyme Decon (Biological): DoD DARPA

The goal of the DARPA Enzyme Decontamination program is to provide an environmentally friendly, enzyme-based formulation that is capable of rapidly restoring a BW contaminated environment. DARPA collaborator, Maxygen Incorporated, is using its proprietary Molecular BreedingTM directed molecular evolution technology to rapidly evolve industrial enzymes towards new and better catalytic properties for spore killing. Two unique sets of enzymes are currently under development. The first set, specific for sequential spore coat and cortex degradation, consists of a collection of enzymes enhanced for complex polymer degradation. The second set consists of enzymes capable of generating compounds with strong sporicidal and bactericidal activities. Research and development within this effort has led to the generation of the antimicrobial oxidoreductase system for spore killing. This system relies on

oxidative halide compounds generated by haloperoxidase enzymes, or organic radicals formed by laccase or peroxidase enzymes. In-house studies on surrogate spores have demonstrated effective decontamination when applied to different surfaces. The current product is sufficiently mature for field trials. Further research will involve enzyme optimization through DNA shuffling and high-throughput screening, which will produce the most successful decontamination system.

Solution Chemistry: DoD DARPA

The focus of the DARPA Solution Chemistry Program is to develop nanomaterials that will serve as antimicrobial agents that can also be used as BW decontaminants. Nanomaterials development is modeled after the immune system in that nanomaterials also involve redundant, non-specific and specific forms of pathogen defense and inactivation. The first nanostructure is an emulsion containing vegetable oil, surfactants and solvents. This material is less than 500 nm in diameter and can be stored for prolonged periods of time without special precautions. The nanoemulsion inactivates bacteria, viruses, fungi and spores through size-dependent disruption of the organism, but is non-toxic. The lack of toxicity also allows this material to function as a pathogen avoidance barrier and post-exposure therapeutic agent applied in a topical manner to wounds, skin and mucous membranes. This material has been field tested as a decon agent and found to reduce *Bacillus* spore count by a million fold over a 24 hour period. It has also been effective in treating wounds contaminated with either *Bacillus* or *Clostridial* spores. The DARPA Solution Chemistry program was completed in FY01. Research was performed at the University of Michigan. The program transitioned to USAMRIID in FY01 and is scheduled to transition to JSFDS (Blk III) in FY03.

DF-100/200 (Sandia Foam): DOE CBNP

A non-toxic, non-corrosive aqueous foam with enhanced physical stability for the rapid mitigation and decontamination of CBW agents has been developed at SNL. This technology is attractive for civilian and military applications for several reasons. It requires minimal logistics support, and a single decon solution can be used for both CW and BW agents. Mitigation of agents can be accomplished in bulk, aerosol and vapor phases, and it can be deployed rapidly. The technology exhibits minimal health and collateral damage and is relatively inexpensive. It also has minimal run-off of fluids and no lasting environmental impact. The foam can be delivered by various methods. One preferred method is based on an aspiration, Venturi effect, which eliminates the need to pump additional air into a closed environment and minimizes the transport of CBW agents to uncontaminated areas. Results to date have shown effective decontamination of both CW and BW agent simulants and live agents on contaminated surfaces and in solution. More recent results have shown that the foam effectively kills anthrax spores and successfully neutralizes TGD (thickened soman), VX and HD. The foam was demonstrated in the Fixed Site Decon Trials at the Edgewood Chemical Biological Center (ECBC) in FY99-00 (shown as DOE Miscellaneous Testing). The foam was also demonstrated at the Decontamination Field Trials in FY99-00 and during RestOps ACTD in FY00-01. The formulation has been successfully deployed through spraying and fogging devices in preliminary experiments. The FY01-02 primary efforts are foam optimization, further engineering of foam deployment systems, technical support to our commercial partners, field testing in both civilian and military settings and alternative deployment methods (i.e., spray applications).

Peroxymonosulfate Oxidizers (L-gel): DOE CBNP

The LLNL peroxymonosulfate research is focused on the evaluation of various oxidizer systems as reagents to allow for CB agent detoxification and/or degradation to nontoxic, environmentally acceptable components rather than necessitate complete destruction. In order to maximize the contact time between the decontaminating reagent and the contaminant agent, gelled reagents were selected as the primary carrier material. Gels have the additional advantage

of adhering to vertical and even the underside of horizontal surfaces such as ceilings and walls. The primary decontamination system now under development at LLNL is based on the commercial oxidizer "oxone" manufactured by DuPont. The active ingredient is potassium peroxymonosulfate. LLNL's work built on previous research at Edgewood Chemical and Biological Center (ECBC), which demonstrated the effectiveness of aqueous Oxone in decomposing both VX and Mustard type agents. Experimental testing on both surrogates and real chemical agents has further shown that only RO• (peroxyl) oxidizers are effective for complete CW decontamination. This formulation was also found to be effective for all BW spore surrogates as well as live vaccine strains (*B. anthracis* Sterne). To date, the gelled system has successfully been tested with a complete suite of CW and BW surrogates. ECBC has been involved in the laboratory evaluation and field testing of L-gel. Real CW agent testing has been completed by ECBC where L-gel was found to reduce VX, HD and GD below detectable limits on all surfaces tested. L-gel was tested in FY99-00 during the Decontamination Field Trials, FY00 during the Fixed Site Decon Trials (CBDP Miscellaneous Testing) and in FY00-01 during RestOps ACTD. During FY00 all laboratory and field testing was finalized on live CW and BW agents. Tests also demonstrated L-gel to be effective against the biological toxin surrogate ovalbumin. The roadmap shows FY02 transition opportunities for L-gel to include the Superior Decon System, CASPOD and the commercial sector.

L-gel (Solid Water): DOE CBNP

The L-gel effort also includes a "Solid Water" aerosolized form of the liquid decontaminant for use in ventilation ductwork or other confined spaces. Based on the Dry Water concept developed by DeGussa Corporation, nanoparticles of hydrophobic silica are produced and then used to coat aerosolized water droplets, capable of delivering 80-95% 1N oxone solution directly to chemical agents. Preliminary results demonstrate decontamination of CW surrogates in 30 minutes. L-gel Solid Water transition opportunities include the Superior Decon System and the commercial sector at the end of FY04.

Electrostatic Decontamination System (EDS): TSWG CBRNC

The objective of this TSWG Task is to develop and test a field prototype decontamination system using a battery operated man-pack, photoactivated liquid decontamination system for CB agents and persistent toxic industrial chemicals (TICs). The system comprises an intense pulsed, lightweight, portable, battery powered Ultraviolet (UV) Light Source Unit and a Photosensitizer Sprayer Unit. The EDS uses a photosensitized UV process with electrostatic spraying for efficient low-drift loss photosensitizer application. The UV activation of the photosensitizer results in significant improvement of the kinetics and effectiveness of the decontamination reaction. The laboratory validation of the preliminary system design will be completed to include evaluation of the EDS effectiveness against simulants and actual CB threat agents. The preliminary design and laboratory evaluations will provide technical data for the final design, rapid prototyping and testing of the field prototype EDS. This program will begin in FY02 with the final design completed in FY03. Transition into the commercial sector is scheduled for the end of FY03.

Oxidative Formulations DTO: DoD CBDP

The objective of this DTO is to develop a non-corrosive, material compatible, non-toxic and environmentally friendly oxidative CB decontaminant to replace DS2 and STB/HTH. This DTO will consist of four main R&D efforts, which include Decon Green, Surfactant Based Decontaminating Solution, Dioxiranes and Decon Formulation. An oxidative formulation will be effective against standard CWAs, FGAs and biological agents. Since this effort uses a formulation approach, it will allow for the incorporation of enzymes and polymeric catalysts (DTO CB.09), a DARPA-developed biological decontamination solution and other reactive technologies into one formulation with a peroxy-based oxidant serving as the primary reactive

component. Multiple reactive components in a pH range of 7.5–9.0 will allow either oxidation or displacement reactions that yield acceptable reaction products. Water-soluble components and simple *in-situ* mixing will make the formulation compatible with existing military or COTS decon applicators. The DTO initiates in FY02 and ends at Superior Decon System transition in FY06 with a down-select among the research efforts to occur at the end of FY04.

Decon Green: DoD CBDP

Decon Green will be a universal decontaminant for VX, GD and HD based on relatively non-toxic, environmentally acceptable materials such as baking soda, hydrogen peroxide and a co-solvent. All materials are commercially available within a broad industrial base. The product will be two solutions plus a catalyst that can be easily mixed then applied by existing decon apparatuses or expedients. The decontaminant will be an organic system that can be used with fielded decon equipment or COTS high pressure sprayers. It will be a dual-use chemical and biological decon, effective against VX, GD and HD as well as *Bacillus anthracis* spores. In addition, it will be relatively non-toxic and considerably less corrosive than current decontaminants. The current Decon Green formulation combines hydrogen peroxide with a co-solvent and catalyst to provide an effective broad based organic decontaminant effective against CBW agents. Another distinct advantage of this decontaminant is that it will not freeze at sub-zero temperatures (down to -31°C), nor will its effectiveness decrease due to high temperatures (up to 49°C). The roadmap shows transition opportunities for Decon Green to include CASPOD in FY02. Decon Green is among the Oxidative Formulations candidates that may transition into the Superior Decon System in FY06.

Surfactant Based Decontaminating Solution: DoD CBDP

The objective is to develop a replacement for the current decontaminating solutions (DS2 and HTH) with a chemical and biological agent decontaminating (decon) solution utilizing two technologies. These technologies are surfactant (microemulsion) and peracid chemistry, which will meet the need for an effective dual use decon solution that is noncorrosive to materials and does not present a hazard to the user or the environment. Microemulsions afford a means of dissolving the organic chemical agents and inorganic, reactive decontaminating components in one solution, without the need of environmentally unfriendly solvents. Microemulsions also have very low interfacial tensions which will enhance their ability to sorb into agent contaminated coatings to bring the reactive decon components into contact with the chemical agents. The peracid precursor offers a unique means of incorporating an environmentally friendly, strong oxidizer that is reactive at a mild pH (noncorrosive to materials). The peracid eventually breaks down into the weak acid and water. There are many forms of the peracid precursor, used in the laundry industry, with varying solubility and surface active properties. Although not as far along as Decon Green in its development cycle, initial efficacy results for the Surfactant Based Decontaminating Solution on CB agents appear very promising. Surfactant Based Decon is among the Oxidative Formulations candidates that may transition into the Superior Decon System in FY06.

Dioxiranes: DoD CBDP

The objective of this effort is to explore the effectiveness of dioxiranes as a decontaminant for chemical and biological warfare agents. This effort will determine the stoichiometry and kinetics of reaction of dioxiranes with simulants representing the main classes of chemical (H-, G-, V-agents) and biological (bacteria and their spores) agents and identify the products of reaction. Initially, dimethyldioxirane (DMDO) will be used for proof of concept, however, longer alkyl changes may be required. Positive results will be confirmed by reaction with active agents and conditions for practical use as a decontaminant will be defined. Dioxiranes constitute a new class of powerful oxidants and have been used (mainly DMDO) extensively as

powerful oxidants capable of carrying-out a variety of synthetically useful oxidations under mild conditions. To date, the dioxirane effort has shown that these oxidants are very effective against biological agents and a limited test bed of chemical warfare simulants. The ultimate goal of this effort is to provide a viable component for the Superior Decon System formulation effort. Dioxirane decontamination is among the Oxidative Formulations candidates that may transition into the Superior Decon System in FY06.

Solid Phase Chemistry

The intent of this thrust area is to investigate and validate cost effective deactivation and destruction of CW agents rapidly by solid matrices, extending the technology to areas beyond sorbent decon. The reaction chemistry of agents with novel nanomaterials is a component of this thrust. Emphasis areas include reactive nanoparticles and reactive decon coatings. Leveraging efforts include DARPA MURI efforts and Nantek, Incorporated nanoparticles.

Destructive Adsorption: DoD CBDP

This project covers the rudimentary work currently going on in CBDP solid phase efforts that may possibly support sensitive equipment as well as other programs for DoD. Transition opportunities for this technology include JSSED Blk I in FY04 and Next Generation Decon Kit in FY09.

Gas Phase Chemistry

The goal of this thrust area is to develop gaseous solvents that have superior solubility for chemical agents while also meeting safety, health environmental and material compatibility requirements. Although technically not a gaseous phase product, plasma based systems form a subset of this area. Emphasis areas include reactive gases, plasma-based systems and supercritical carbon dioxide. Leveraging efforts include the LANL Atmospheric Pressure Plasma system.

Reactive Gas Phase Reagents: DOE CBNP (LANL)

This work is focused on investigating the use of gas-phase ozone and chlorine dioxide systems for CBW decontamination. While liquids, gels and foam-based reagents should be effective in decontaminating exposed surfaces, reactive gases will be necessary to "complete" a full decontamination since gases are the only practical means of getting into small cracks, cul-de-sacs, micro-porous materials and air ducts. Gaseous ozone demonstrated, under the right environmental conditions, to be an effective reagent against biological agent surrogates in as little as one-half hour. Bacterial spores appear to be slowly dissolved upon contact with ozone. Times on the order of a day or two may be required for the most persistent chemical agents. For releases within civilian facilities, these times are still believed acceptable. Studies using other candidate gases (for example, chlorine dioxide) will be initiated. Results will be correlated into a form suitable to responders & planners in order to provide the best strategy for a given scenario. This technology is planned to transition into the commercial sector at the end of FY02.

Plasma: DoD CBDP

The objective of this effort is to evaluate new plasma technologies for application to sensitive equipment decontamination including vehicle interiors. This is a highly leveraged effort that is considering plasma technologies under development at other government agencies (including DOE) as well as in academia and commercial industry. The DoD plasma effort began in FY99 with chemical agent decontamination efficacy studies on the LANL APPJ technology. Although the outcome of the decon efficacy studies was promising, several technical challenges precluded pursuing plasma approaches at that time. Hence, the plasma efforts at DOE and other commercial and academic facilities were put in a "technology watch" status by DoD. Recent advances in the field of plasma science are very encouraging and many of the technical

challenges noted in the FY99 study have been addressed. To gauge the progress made, DoD is conducting a two-year effort that began in FY02 to assess plasma technologies and potentially support the development of promising candidates for use in sensitive equipment decontamination. Transition opportunities for this technology include JSSED Blk II/III in FY05.

Supercritical Carbon Dioxide: DoD CDBP

The objective of this effort is to develop an approach for sensitive equipment decontamination using dense gas phase carbon dioxide. When gaseous carbon dioxide is compressed and heated beyond its critical point, it begins to take on physical properties similar to that of a liquid solvent. By operating above the critical point, the dense gas phase region, changing the pressure and temperature will influence the density and thus solvent power. Phase boundary measurements indicate that the chemical agents HD, GB and VX are highly soluble in carbon dioxide at conditions near the critical point. The current focus is on:

- dynamic and static tests to define phase boundaries,
- decontamination efficacy tests using a range of materials (i.e. plastics, elastomers, painted surfaces),
- material's compatibility tests,
- adsorption testing as a means to re-circulate liquid carbon dioxide and
- bench-scale extractions using chemical agent surrogates.

Transition opportunities for this technology include JSSED Blk I in FY03.

Powered Decontamination Systems (APPJ): DOE CBNP

The objective of Atmospheric Pressure Plasma (APP) technology is to convert a mix of innocuous gases, such as helium and oxygen, into a reactive gas stream capable of detoxifying CBW agents. This is accomplished by passing the feed gas through a plasma (e.g. an ionized gas consisting of ions, electrons and neutrals) where it becomes chemically activated through collisions with energetic electrons. APP decontamination devices may provide a much needed method of CBW decon which, unlike traditional decon methods, is dry and nondestructive to sensitive equipment, such as electronics and irreplaceable objects. This would provide a fast and portable means of restoration of contaminated items for which the only current option is ultimate disposal. These devices would rely heavily on the novel Atmospheric Pressure Plasma Jet (APPJ) technology which has been developed at LANL over the past five years and was a winner of a 1999 R&D 100 Award. APPJ has been shown to kill *Bacillus globigii* (BG) spores, a surrogate for anthrax. Collaborative testing with ECBC has also shown APPJ to neutralize surrogate and actual CW (VX) agents. Several techniques are also being evaluated for use in an APP Decon Jet for decontamination of sensitive equipment and materials that cannot be placed inside a chamber. This device would be most useful for spot decontamination of interior spaces containing these items such as airplanes, control centers for commercial communications, power and transportation facilities as well as conventional office space. Transition opportunities for this technology include JSSED Blk II/III and the commercial sector in FY03.

Supporting Technologies

Mass Decontamination Protocols: TSWG

During FY01, TSWG CBRNC users were focused in two areas: 1) Scientifically validated and consensus-based personnel decontamination procedures for employment with civilian personnel; and 2) management of contaminated animal and plant materials. Mass Decontamination Protocols develops science- and consensus-based best practices for the decontamination of a large number of civilian victims of a biological agent, a toxic industrial chemical, a persistent chemical warfare agent and a non-persistent chemical warfare agent. The

military procedures may not be well suited for civilian use. International partners are participating in the development of these protocols. Intended users are Public Health Service and Civilian HAZMAT Units. Current key technical issues include identifying scientific basis for current personnel decon practices and their applicability to the civilian community. Mass Decontamination Protocols were incorporated into USPHS training at Noble Hospital in FY01. Key Near-Term Objectives include publication of consensus statement in a peer-reviewed journal for the commercial sector in late FY02.

Decontamination/Restoration Methodology: DOE CBNP

The CBNP Decontamination/Restoration Methodology program is focused in two areas:

- How Clean is Clean Enough?
- How Clean is Safe?

The objective of the first area is to investigate required clean-up levels and related regulatory issues while the second area is centered on improving the technical basis for decontamination/restoration following a WMD event. In the context of a potential release of CBW agents, three kinds of sites may bound the response and decontamination approach to be taken. They are:

- An outdoor site, such as a stadium or campus,
- A semi-enclosed site, such as a subway or airplane hangar
- An indoor environment, such as an office building, home, room or airport terminal.

The overall issue of "How Clean is Clean Enough?" and the methods by which this is determined (e.g., sampling and verification) is key to establishing effective and successful decontamination methods. Therefore, the primary goal of this effort is to establish a methodology to determine the level of clean-up required to meet both regulatory and stakeholder needs. During FY01, a complete, detailed CW risk assessment was generated.

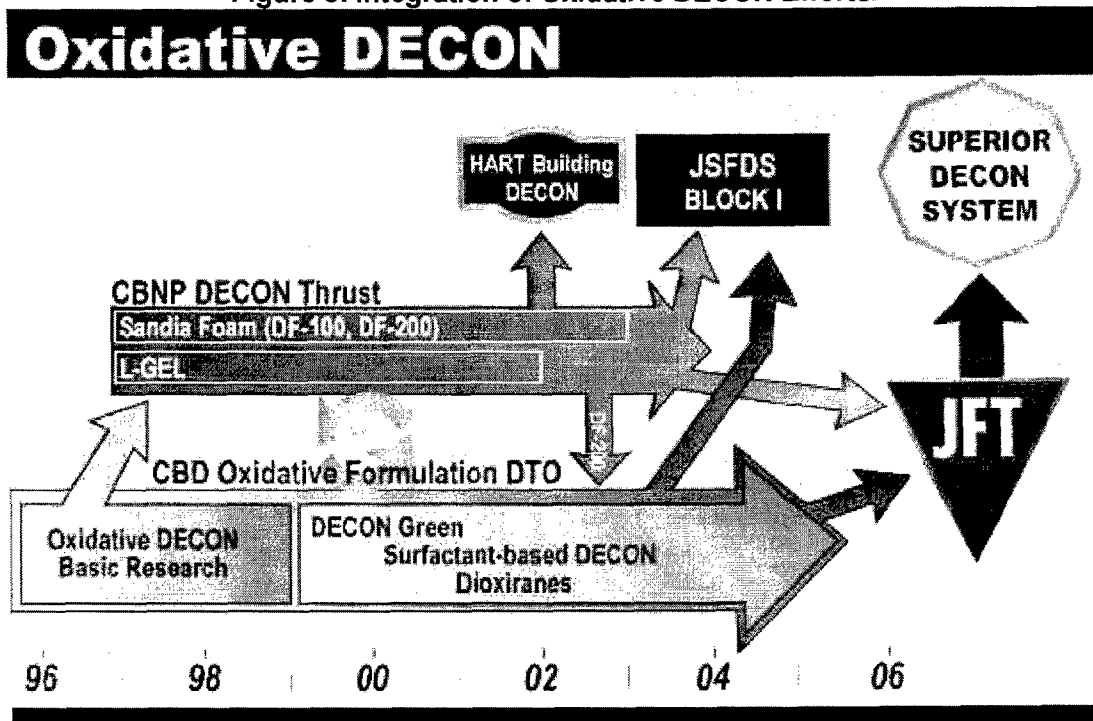
To address "How Clean is Safe", in FY01 ORNL conducted an analysis of lessons learned from previous decontamination experiences. There are considerable number of decontamination experiences that can improve the basis for decontamination and recovery planning. These events have never been documented in a systematic fashion nor examined for the lessons learned. Such documentation is essential to developing effective protocols and providing consistent and valid information to the public on the appropriate procedures for decontamination and other safe protective measures. During FY01, case study reports and a final lessons-learned report will be completed.

APPENDIX C

Integration Example: Decontamination Using Oxidative Chemistry Approaches

Oxidative chemical approaches form the basis of the solution chemistry thrust effort of both the Department of Defense and Department of Energy decontamination programs. As such, DoD and DOE have a number of efforts in oxidative chemistry that are at various stages of development. This appendix provides background on the state of oxidative chemistry research within these two agencies, as it applies to the development of solution phase chemical and biological warfare decontaminants. It then describes each of the efforts conducted under these programs, the interrelatedness of the two programs, and the steps taken toward maximizing leverage among the programs and preventing duplication of efforts. Figure 9 shows DoD and DOE past and planned oxidative chemical decontamination program integration efforts.

Figure 9. Integration of Oxidative DECON Efforts.



Background

Various oxidative solutions such as hydrogen peroxide, peroxyacids and potassium peroxymonosulfate have been used for years in disinfecting biological warfare agents. Although investigators had considered these types of oxidative methods over the years for decontaminating chemical warfare agents, it wasn't until the early 1990's that DoD began to realize the full potential of these and other oxidative approaches. Early basic research on peroxy-based approaches conducted at the Edgewood Chemical Biological Center (ECBC) set the stage for several successful decontamination programs in both DoD and DOE.

Oxidative chemical approaches are very attractive for use as decontaminants for several reasons, which include:

- Their efficacy toward both chemical and biological agents,
- Their considerably lower toxicity than traditional chemical agent decontaminants,
- The relatively environmentally benign nature of the oxidative decontamination solutions, and
- The formation of less toxic, more manageable reaction products during the process.

For example, hydrogen peroxide decontaminates the nerve agent VX, yielding reaction products of low toxicity. This chemical agent is particularly difficult to decontaminate since many of the potential products from reactions with VX yield substances that are extremely toxic. Failure to cleave the P-S bond that occurs with some nucleophilic decontamination processes yields EA2192, a relatively persistent product, the toxicity of which approaches that of some of the G-series nerve agents. Decontamination using hydrogen peroxide, however, rapidly breaks the P-S bond in VX and yields more manageable reaction products.

DoD Oxidative Chemistry Efforts

The oxidative chemical decontamination approaches described in this section are funded and managed as part of the Joint Science and Technology Panel for Chemical and Biological Defense (JSTPCBD) Tech Base Research Program. In order to coordinate efforts within this area, the JSTPCBD Business Area Manager for Decontamination established the Defense Technology Objective (DTO) 44, Oxidative Formulation. The objective of DTO 44 is to develop a non-corrosive, material compatible, non-toxic and environmentally friendly oxidative CB decontaminant to replace the current military decontaminants, DS2 and STB/HTH. Currently there are two oxidative decontaminants under development in DTO CB.44, Decon Green and the Surfactant-Based Decontaminating Solution. Both of these developmental decontaminants, as well as a promising approach using dioxiranes, will be described below.

Decon Green

In 1997 after extensive basic research on peroxide solutions as decontaminants, ECBC scientists pointed out that a peroxide-based solution containing co-solvents is a potential broad-spectrum decontaminant for HD, VX and G agents. Furthermore, such decontaminants would avoid the formation of toxic by-products created using chlorine bleach formulations. ECBC, continuing its research on peroxide-based solutions, has now created Decon Green, a sophisticated peroxide-based solution that is as effective as DS2, but does not have hazardous side effects. This solution was designed specifically to meet military needs.

Decon Green combines hydrogen peroxide with a co-solvent and catalyst to provide an effective broad based organic decontaminant effective against chemical and biological warfare agents. Another distinct advantage of this decontaminant is that it will not freeze at subzero temperatures (meets the current -31°C low temperature requirement), nor will its effectiveness decrease due to high temperatures (up to 49°C).

Surfactant-Based Decontaminating Solution

Another promising effort under development in the Decontamination Tech Base Program is the Surfactant-Based Decontaminating Solution that combines a microemulsion with an oxidative peracid solution. Formulations combining a microemulsion with the peracid precursor have demonstrated great potential for chemical and biological agent decontamination. Peracids are known to possess high disinfectant activity against endospore forming bacteria, vegetative cells and viruses. Microemulsions afford a means of dissolving the organic chemical agents and

inorganic, reactive decontaminating components in one solution, without the need for environmentally unfriendly solvents.

The peracid precursor offers a unique means of incorporating into the decontamination solution an environmentally friendly, strong oxidizer that is reactive at a mild pH (noncorrosive to materials). The peracid eventually breaks down into a weak acid and water. There are many forms of the peracid precursor, used in the laundry industry, with varying solubility and surface active properties. Although not as far along as Decon Green in its development cycle, initial efficacy results for the Surfactant-Based Decontaminating Solution on chemical and biological agents appear very promising.

Dioxiranes

Although not currently part of DTO CB.44, the Tech Base dioxirane effort also appears very promising. Dioxiranes constitute a new class of powerful oxidants, first prepared in 1979, by reaction of caroate with a ketone. Since that time, dioxiranes, mainly dimethyl dioxirane (DMDO), have been used extensively as powerful oxidants capable of carrying out a variety of synthetically useful oxidations under mild conditions. To date, the dioxirane effort has shown these oxidants to be very effective against biological agents and a so-far limited set of chemical warfare simulants.

DOE Oxidative Chemistry Efforts

The DOE oxidative products described in this section were developed with funding provided by the U.S. Department of Energy's and National Nuclear Security Administration's Chemical and Biological National Security Program (CBNP). Within the CBNP program was the Decontamination and Restoration Initiative that attempted to develop rapid, effective and safe decontamination technologies for the restoration of civilian facilities in the event of a domestic terrorist attack. Development of these technologies focused on three scenarios: open air, semi-enclosed and enclosed facilities. In addition, the needs for these technologies focused on two general areas, decontamination capabilities for the first responder and facility restoration or remediation.

DF-100/200

Under the CBNP charter and leveraging the early basic research efforts in peroxy-based decontamination conducted at ECBC in the early to mid 1990's, the Sandia National Laboratory began development of DF-100 in 1997. DF-100 is an aqueous foam-based decontamination product that uses hydrogen peroxide as its active component and combines surfactants, carbonates and various foam components to yield a very effective aqueous based decontaminant. The oxidative nature of DF-100 yields desirable reaction products and recent testing by DoD at both ECBC and Dugway Proving Grounds indicates that the product is effective for neutralizing both chemical and biological agents and also works on a number of anticipated material surfaces.

Although DF-100 was developed under the CBNP program for domestic scenarios, it has great potential for use in military decontamination operations. As such, DoD has considered this product for a number of military applications including the Joint Service Family of Decon Systems Program, The Restoration of Operations (RestOps) Advanced Concept Technology Demonstration (ACTD) and the Contamination Avoidance for Seaports of Debarkation (CASPOD) ACTD.

In 2001, SNL completed an upgrade of DF-100, called DF-200, that improved the product's efficacy on chemical and biological agents and addressed some of the concerns raised by DoD in using DF-100 in a military scenario. To assist in the development of DF-200 for use

in military operations, the JSTPCBD funded a two-year effort under the CB3 Technology Transfer program beginning in 2002. Work is currently under way at both Sandia National Labs and ECBC and is being coordinated by the JSTPCBD's Business Area Manager for Decontamination.

L-gel

In a parallel effort under the CBNP program, Lawrence Livermore National Labs (LLNL) began production of a gel-based oxidative decontaminant, L-gel, that uses "Oxone", a commercial preparation of potassium peroxymonosulfate as its active component. Previous research at ECBC demonstrated the effectiveness of oxone in decontaminating VX and mustard agents. Unfortunately the efficacy of oxone on G-type agents was slow under normal conditions. LLNL incorporated a fumed silica gelling agent into the oxone solution. The fumed silica gave the solution its characteristic "gel-like" property, but it also catalyzed the hydrolysis of G-agents, giving a broad-spectrum chemical efficacy to the product. Recent advances in the product include the development of a "solid water" aerosolized form of the liquid decontaminant, making it deliverable to ductwork and other confined spaces.

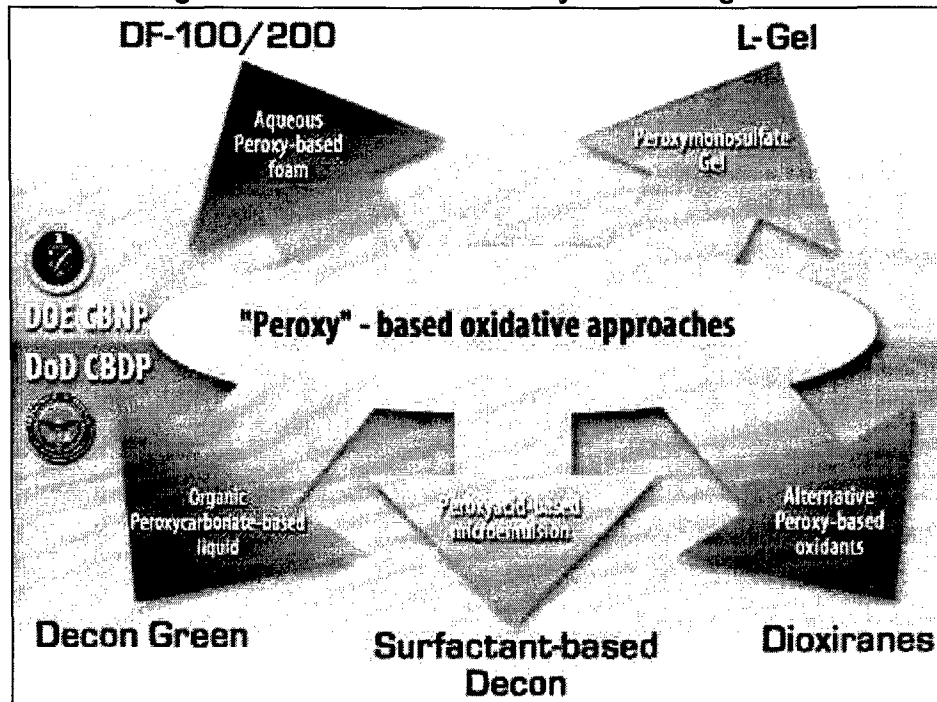
Development of Cooperative Effort

Development of decontamination solutions that are based on oxidative chemistry approaches clearly exemplifies the close interaction between DoD and DOE decontamination development programs. Figure 10 shows how the DoD and DOE solution phase oxidative chemistry programs focus on a central approach of incorporating peroxy-containing species as the active component in their decontamination solutions. Although the peroxy approach is a common thread amongst the developmental programs, Figure 9 shows that the final product and overall approach employed by each individual development program is vastly different. This common thread allows the various investigators to maximize leveraging opportunities while minimizing redundancy among the projects.

It is important to remember that although the projects shown on Figure 10 use a similar active ingredient, they are producing vastly different products, each with its own particular characteristics. For example, DF-100/200 and Decon Green both use hydrogen peroxide as the active component, but their base formulations are drastically different. The DF-100/200 products are aqueous-based solutions that can be concentrated and later mixed with water onsite to provide the decontaminant. This characteristic is particularly beneficial from a logistical and application standpoint, but some sacrifices are made because many chemical agents and thickeners are organic compounds and not very soluble in aqueous solutions. The degree to which the product is soluble is critical from the standpoint of decontamination efficacy, since one of the primary factors that dictates efficacy is the solubility of the chemical agent in the decontaminant. Decon Green on the other hand is an organic solution; chemical agents and thickeners are very soluble in this solution. The organic nature of Decon Green, however, makes concentration difficult, which can be problematic for both logistics and the application.

The other products shown on Figure 10 are unique variants of the "peroxy" oxidative approach, each approaching the problem of chemical and biological decontamination in a slightly different manner. At this stage of development, it is difficult to say which peroxy-based approach will be the best, or even if a single "best approach" exists.

Figure 10. DoD and DOE Peroxy-Based Programs.



The two-year DF-200 CB3 Technology Transfer effort described earlier further exemplifies the close interaction amongst DoD and DOE. The Department of Energy initially leveraged basic research done by DoD and developed an effective product for a domestic response scenario. The Department of Defense recognized the potential of DF-200 and provided recommendations on ways to improve the product to meet military requirements and ultimately incorporated advanced development and testing efforts into its 6.3 level program. These efforts will not only provide an improved product for DOE to use in domestic response scenarios, it will provide DoD with an effective aqueous-based oxidative decontamination solution.

As cited earlier, there has been a great deal of leveraging between DoD and DOE on the oxidative chemistry program. The principal investigators (PIs) have jointly attended multiple meetings, workshops and symposia on these projects. Of particular note are the 2000 New Concepts in Decontamination Workshop co-sponsored by the JSTPCBD and the Army Research Office and the annual DOE CBNP Summer Meetings. To ensure leveraging continues in this area, the JSTPCBD Business Area Manager is serving as a liaison between DOE researchers and the PI's working on the DoD funded efforts. This formalized coordination will minimize the potential for organizational conflicts of interest and will ensure that, when appropriate, DOE technologies have a link to DoD decontamination activities. In the case of DF-200, this coordination has been very successful. Thus, such collaborative efforts will continue whenever appropriate opportunities exist.

Use of DF-100 in Response to the October 2001 Anthrax Incidents

DF-100 was used to help remediate office buildings on both Capitol Hill and in New York City which were contaminated as a result of the anthrax incidents of late 2001. Immediately after the Hart Senate Office building became contaminated, DF-100 (supplied by Envirofoam Technologies, Inc.) was evaluated in government-sponsored tests against live, vaccine-strain anthrax spores at Johns Hopkins Advanced Physics Laboratory. Also included in the tests was bleach (as a control) and the NanoBio, Inc. Nanoemulsion formulation. Since DF-100

outperformed both bleach and the Nanoemulsion formulation in these tests, it was selected to be used to remediate selected areas of the Capitol Hill office buildings. Over the next few weeks, DF-100 successfully remediated a large mailroom facility in the Ford House Office Building, a large mailroom in the Dirksen Senate Office Building, and selected hallways, stairways and a freight building in the Hart Senate Office Building. Post-sampling indicated complete kill of anthrax spores and surrogate spores placed for verification purposes. There was minimal collateral damage in the first application (the Ford mailroom) due to overapplication of the foam which was a result of operator inexperience. No collateral damage was noted in the second and third applications (in the Dirksen and Hart Buildings).

DF-100 (supplied by Modec, Inc.) was also used to successfully remediate the ABC News Building and New York Post Building in New York City. In this case, DF-100 was applied as a fog using commercial, off-the-shelf cold fogging units. Post-sampling indicated successful kill of the anthrax spores. No negative health effects have been noted in either building.

In November 2001, the U.S. EPA issued crisis exemption permits to both Envirofoam Technologies, Inc. and Modec, Inc. to allow sales of the DF-100 product to military and paramilitary entities for use in response to terrorist attacks utilizing biological agents. These permits were issued because both Sandia and government-sponsored tests (both in the laboratory and in the field) and actual field data from the anthrax incidents indicated that DF-100 would kill anthrax spores. From a regulatory standpoint, the Environmental Protection Agency took this action so that the companies' products could be used during the anthrax crisis without immediately satisfying the lengthy EPA registration process. On March 28, 2002 the EPA rescinded the crisis exemptions since the immediate need to use the product has passed. Both companies are performing and documenting the tests necessary to obtain permanent EPA registrations as a sporicide.

Conclusion

Oxidative chemical approaches are very attractive for use as decontaminants for a variety of reasons. Researchers at both the Department of Defense and the Department of Energy have succeeded in advancing this technology to the point where the efficacy of oxidative decontaminants exceeds that of currently fielded decontamination products. Through programs such as the DoD CB3 Technology Transfer Program and the continual interaction of DoD and DOE scientists, it is reasonable to assume that an oxidative replacement of DS2 and STB/HTH for use in military chemical and biological warfare agent decontamination operations will be achieved in the very near future.

The timeliness of this research and development could not be clearer. In the aftermath of the October 2001 anthrax incidents, several facilities required decontamination, a daunting task made easier as a result of this cooperative investment in decontamination research and development.

APPENDIX D

Congressional Language Calling for the Integration Effort

Senate Armed Services Committee Language, S. Rpt. 106-50 S. 1059

"In 1996, the CPRC recommended that the Department of Defense and the Department of Energy establish an integrated research, development, and acquisition plan for technologies associated with chemical and biological counterproliferation. To date, there has been no visible result of this CPRC recommendation. The committee directs the Under Secretary of Defense for Acquisition and Technology to submit the integrated plan to the congressional defense committees, not later than March 1, 2000."

Senate Armed Services Committee Language Requiring a Report on CPRC Integration with Domestic Response Users

"In 1996, Congress added a mission to the CPRC charter requiring efforts to '...negate paramilitary and terrorist threats involving weapons of mass destruction.' Given this responsibility, and the resources and expertise available to the CPRC, the committee believes that the CPRC should consider establishing a mechanism for working with the domestic response program to help ensure that the research, development, and acquisition of equipment for domestic response to weapons of mass destruction has appropriate involvement from the user community. The committee directs the CPRC to provide a report to the congressional defense committees, not later than March 15, 2000, on this recommendation and its potential benefit to the domestic response program."

APPENDIX E

List of Acronyms

ACEs	Areas for Capability Enhancements
ACTD	Advanced Concept Technology Demonstration
AIDET	Aircraft Interior Detector
AMB	Advanced Multifunction Biochip
APDS	Autonomous Pathogen Detector System
ATD	Advanced Technology Demonstrations
BAM	Business Area Manager
BASIS	Biological Aerosol Sentry and Information System
BCAS	Biological Combat Assessment System
BSPS	Bio Sample Prep System
BW	Biological Warfare
BWD	Biological Warfare Defense program
CADB	Chemical Agent Detection Badges
CASPOD	Contamination Avoidance for Seaports of Debarkation
CBD	Chemical and Biological Defense
CBDP	Chemical and Biological Defense Program
CBNP	Chemical and Biological National Security Program
CBRNC	Chemical, Biological, Radiological and Nuclear Countermeasures
CCAS	Chemical Combat Assessment System
CDC	Center for Disease Control
CENTCOM	Central Command
CINC	Commander-in-Chief
CP	Counterproliferation Program
CPRC	Counterproliferation Program Review Committee
CRP	Critical Reagents Program
CWICS	Chemical Warfare Interior Component System
DARPA	Defense Advanced Research Projects Agency
DCAS	Domestic Chemical Assessment System
DDAP	Domestic Demonstration and Acquisition Program
DI&W	Detection, Identification and Warning
DNA	Deoxyribonucleic Acid
DoD	Department of Defense
DOE	Department of Energy
DF-100/200	Decontamination Foam-100/200
DPG	Dugway Proving Ground
DTRA	Defense Threat Reduction Agency
ECBC	Edgewood Chemical Biological Center
ELISA	Enzyme Linked Immunosorbent Assay
EMD	Engineering and Manufacturing Development
EPA	Environmental Protection Agency
ESI	Electrospray Ionization
FDA	Force Differentiation Assay
GFE	Government Furnished Equipment
HANAA	Handheld Advanced Nucleic Acid Analyzer
HPLC	High Performance Liquid Chromatography
IC	Intelligence Community

ICDS	Improved Chemical Detection System
IOT&E	Initial Operational Test and Evaluation
ISD	Individual Soldier Detection
IVD	Individual Vapor Detector
JBPDS	Joint Biological Point Detection System
JCAD	Joint Chemical Agent Detector
JCBAWM	Joint Chemical Biological Agent Warfare Monitor program
JFOCs	Joint Future Operational Capabilities
JFT	Joint Field Trials
JHU-APL	Johns Hopkins University Applied Physics Laboratory
JMCBD	Joint Modular Chemical and Biological Detector
JPO-BD	Joint Program Office-Biological Defense
JPSSNS	Joint Portal Shield Sensor Network System
JSMCBD	Joint Service Multispectral Chemical Biological Detector
JSSD	Joint Service Sensitive Equipment Decontamination
JSTPCBD	Joint Science and Technology Panel for Chemical and Biological Defense
LANL	Los Alamos National Laboratory
LFADD	Large Frame Aircraft Decontamination Demonstration
LLNL	Lawrence Livermore National Laboratory
LRIP	Low Rate Initial Production
MAGIChip	Micro Array of Gel Immobilized Compounds on a Chip
MALDI	Matrix-Assisted Laser Desorption Ionization
MASINT	Measurement and Signature Intelligence
NBC	Nuclear, Biological and Chemical
NPAC TWG	Nonproliferation and Arms Control Technology Working Group
OPTEMPO	Operating Tempo
ORNL	Oak Ridge National Laboratory
PACOM	Pacific Command
PCR	Polymerase Chain Reaction
PI	Principal Investigator
PM	Program Manager
POM	Program Objective Memorandum
PROTECT	Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism
PY-GC/IMS	Pyrolysis-Gas Chromatography/ Ion Mobility Spectrometry
R&D	Research and Development
RDA	Research, Development and Acquisition
RDT&E	Research, Development, Test and Evaluation
RestOps	Restoration of Operations
S&T	Science and Technology
SCAMP	Shipboard Chemical Agent Monitor Portable
SESI	Science and Engineering Services Incorporated
SNL	Sandia National Laboratory
SOFCAS	Special Operations Force Chemical Agent Detector
TOF	Time of Flight
TSWG	Technical Support Working Group
UCP	Up-Converting Phosphor
UCPFCM	Up-Converting Phosphor Flow Cytometer
UCPHHA	Up-Converting Phosphor Handheld Assay
USAMRIID	U.S. Army Medical Research Institute of Infectious Diseases